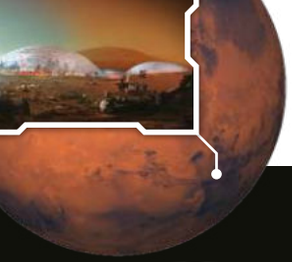

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ANDY WEIR

The Martian author on his next space film

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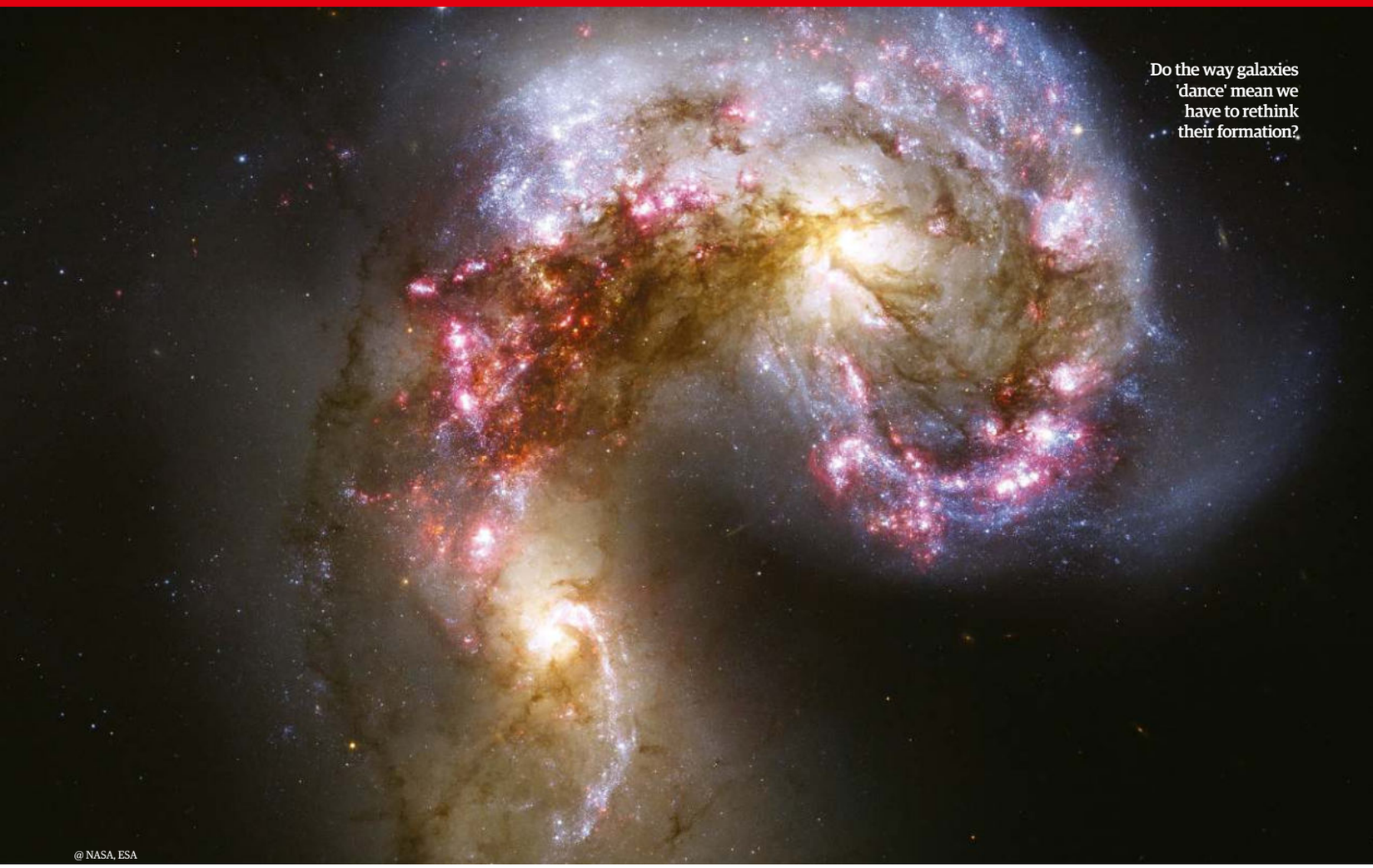

Do the way galaxies 'dance' mean we have to rethink their formation?

Welcome

What happens when a space mission goes wrong? This issue marks the first of a three part series where NASA's greatest astronauts very nearly didn't make it home. Turn to page 16 as Buzz Aldrin retells the story of how a felt-tip pen saved him and Neil Armstrong from becoming stranded on the surface of the Moon, Mike Massimino reveals how he broke the Hubble Space Telescope and was almost electrocuted on the solar panels of the International Space Station whilst Joe Kerwin remembers how he and Pete Conrad was thrown off the hull of the Skylab space station. This issue, there are plenty of nail-biting, edge of your seat moments from NASA and ESA's finest.

If you can't get enough of NASA's astronauts, then we take a trip to the far side of the Moon where Apollo 16's Charlie Duke reveals what he saw on his mission to the lunar surface. We also speak to science fiction author Andy Weir (most famous for *The Martian*) about his next book and the next film in the pipeline as he signs a new deal with 21st Century Fox.

Summer may be here, but there's not to say that you need to pack your observing equipment away - our guide to daytime astronomy is testament to that. From solar, planetary and satellite observing, turn to page 72 for our top tips and tricks without waiting until the small hours.

Gemma Lavender
Editor

"The idea that galaxies should come in from random directions is really not a very good assumption" **Karen Masters, Page 40**

Our contributors include...

Stuart Atkinson
Author & astronomer
Stuart reveals the top sights you can see throughout the lighter, warmer nights and has the tutorials on getting the most out of solar observing - on a budget.

Nick Howes
Astronomer & science writer
Nick spoke to Apollo 16's Charlie Duke about his mission to the Moon, as the astronaut chats about what he saw during his time on the lunar surface..

Colin Stuart
Astronomer & author
It turns out that dancing galaxies have caused us to rethink not just how these structures form and evolve, but also how we see the universe, as Colin reveals on page 40.

Robin Hague
Science writer & physicist
Solar sails are the way forward in getting to asteroids, according to the Japanese Space Agency. Robin uncovers how it'll work on page 32.

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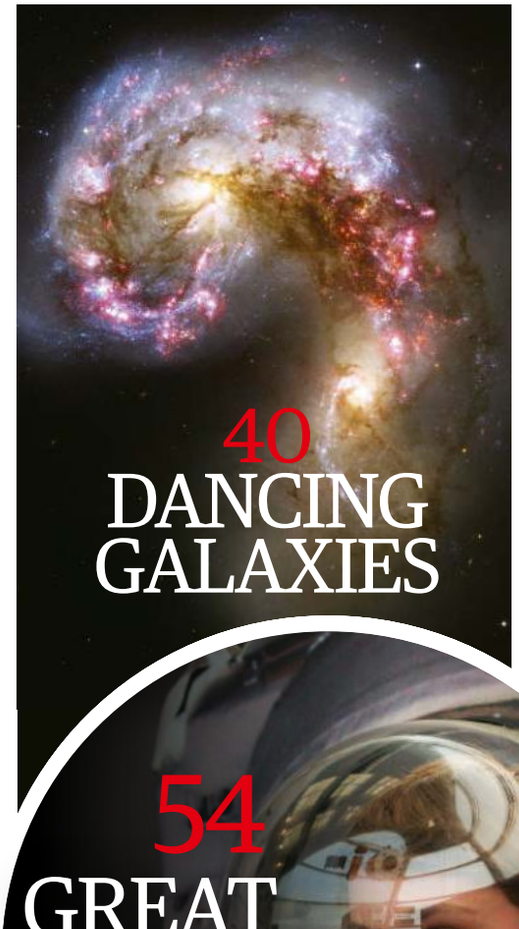

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YOUR FIRST CONTACT WITH THE UNIVERSE

Getting closer to the universe's origins

The Hubble Space Telescope reveals a massive galaxy cluster known as PSZ2 G138.61-10.84, which rests some six billion light years away. It's easy to think that galaxies are randomly distributed through space, but instead they're aggregated in groups, clusters and superclusters. The largest collections of galaxies span over hundreds of millions of light years and contain billions of galaxies.

Our Milky Way is part of a supercluster that is part of the Local Group, which in turn forms part of the giant Laniakea Supercluster. It is thanks to the very same space telescope that we're able to look at these massive galactic superstructures, such as the Hercules-Corona Borealis Great Wall, a giant galaxy cluster that contains billions of galaxies extending 10 billion light years across. It's considered to be the biggest known structure in the universe.

Gullies of a Martian crater

In this image snapped by NASA's Mars Reconnaissance Orbiter, frost in and around two gullies on the surface of the Red Planet is plain to see. This is the Matara Crater, which has been very active with many flows in the last ten years. The flows typically get going when seasonal frost is present – no fresh flows have been seen this year, but the HiRISE camera nestled inside the spacecraft will keep watching.

CHESS 4 mission has lift off!

This stunning scene reveals the launch of the Colorado High-resolution Echelle Stellar Spectrograph, also known as CHESS 4, which was lofted into space on board a NASA Black Brant IX sounding rocket from the Kwajalein Atoll in The Republic of the Marshall Islands. The spacecraft was developed by the Laboratory for Atmospheric and Space Physics at the University of Colorado, Boulder.

CHESS 4's aim is to get a closer look at the interstellar medium, the matter between the stars. The spacecraft focuses on translucent clouds of gas, which provide the fundamental building blocks for stars and planets. These clouds have low densities, meaning that the only way to study them is to measure how a cloud is affected by a star – along with its associated outpouring of stellar material, the stellar wind – moving through it.

NASA celebrates 28 years of Hubble

At the time of writing it has been just over 28 years since the Hubble Space Telescope was lofted into Earth orbit, where it gives us a front-row seat to the universe's extraordinary wonders. To celebrate the landmark, the observatory took this colourful image where a monster young star sits at the centre, shining 200,000-times brighter than our Sun. The stellar heavyweight bathes its immediate vicinity in ultraviolet radiation and hurricane-like stellar winds to carve out a landscape of cavities, ridges and mountains of dust and gas.

This region in the universe is known as the Lagoon Nebula, a vast cosmic nursery where stars are born, which is located some 4,000 light years away. You can see the nebula using a pair of binoculars – albeit not with such vibrancy – as a smudge of light with a bright core.

The gigantic star is known as Herschel 36. It's bursting out of its cocoon of material, unleashing blistering radiation and torrential stellar winds, streams of subatomic particles that push dust away in curtain-like sheets.

A dead star's circle of light

A rich landscape of stars and vibrant, glowing clouds of gas is revealed in this brand-new image from the European Southern Observatory (ESO)'s Very Large Telescope (VLT) in Chile of one of our closest neighbouring galaxies, the Small Magellanic Cloud.

What's particularly brilliant about this image is that astronomers have been able to identify an elusive stellar corpse that has been buried among filaments of gas left behind by a 2,000-year-old supernova explosion. In order to spot it they needed to observe the remnant in X-rays, and that's where the VLT's MUSE instrument – alongside existing Chandra X-ray Observatory data – came in, identifying an isolated neutron star in the system.

The observation solved a several-year-long mystery when they noticed a ring centre on an X-ray source. Astronomers originally designated it p1, soon realising that it wasn't clear if p1 actually lies inside or behind the remnant. "If you look for a point source, it doesn't get much better than when the universe quite literally draws a circle around it to show you where to look," says astronomer Frédéric Vogt.

Planet-making disc around a young star

The SPHERE instrument on the European Southern Observatory (ESO)'s Very Large Telescope (VLT) reveals the dusty disc surrounding a nearby young star in greater detail than ever achieved before. SPHERE works by suppressing the brilliant light of nearby stars, blocking out interference while obtaining a better view of the regions surrounding them. Discs like these are wildly different in size and shape, some containing bright rings and some dark rings, while some even look like hamburgers. They also look different in appearance depending how they're orientated in the sky – from circular face-on discs to narrow discs seen almost edge-on.

SPHERE's primary task is to uncover and study giant exoplanets in orbit around nearby stars with the help of direct imaging – the technique of photographing these distant worlds through their thermal emission. The instrument is also one of the very best tools in existence in obtaining images of discs around young stars, the birthplace of planets starting their life in the universe.

Rainbow skies over Paranal

This stunning view of the European Southern Observatory (ESO)'s Paranal Observatory reveals a spectacular night scene over part of the Very Large Telescope (VLT). Sitting at the centre of the shot is one of the large instrument's four Unit Telescopes (UT). These, combined with four additional movable Auxiliary Telescopes (ATs), comprise the VLT. Hanging above the closed telescope is the colourful plane of our home galaxy, the Milky Way, as it arches across the frame, creating a celestial rainbow.

A portion of the sky is tinted with a faint green colour thanks to a phenomena known as airglow, and two smudges of the Magellanic Clouds can be seen to the left of the UT. Look closely and you'll be able to see the constellation of Orion (The Hunter) visible to the right of the centre. Drawing an imaginary line down and through Orion's Belt reveals red star Aldebaran, which is part of the constellation of Taurus (The Bull). Even further along this imaginary line and down towards the horizon you'll find the Pleiades star cluster (Messier 45).

Stickering-up an Earth Observation spacecraft

Sentinel-3B's sticker is positioned on the rocket fairing, which at the time of print was getting ready for liftoff on 25 April 2018. The satellite is just one craft that forms the European Space Agency's Copernicus Programme, primarily an ocean mission which will also dig deep into the atmospheric and land applications. Its identical twin Sentinel-3A has been in orbit February 2016.

©P. Horálek/ESO

New shot of Jupiter's Great Red Spot

Jupiter's iconic Great Red Spot, surrounded by turbulent zones, has been captured once again by NASA's Juno spacecraft, which has been in orbit around the planetary king since 4 July 2016.

The colour-enhanced image is a combination of three separate images snapped on 1 April as the spacecraft completed its 12th-closest flyby of Jupiter, when it was 24,749 kilometres (15,379 miles) to 49,299 kilometres (30,633 miles) from the tops of the planet's clouds.

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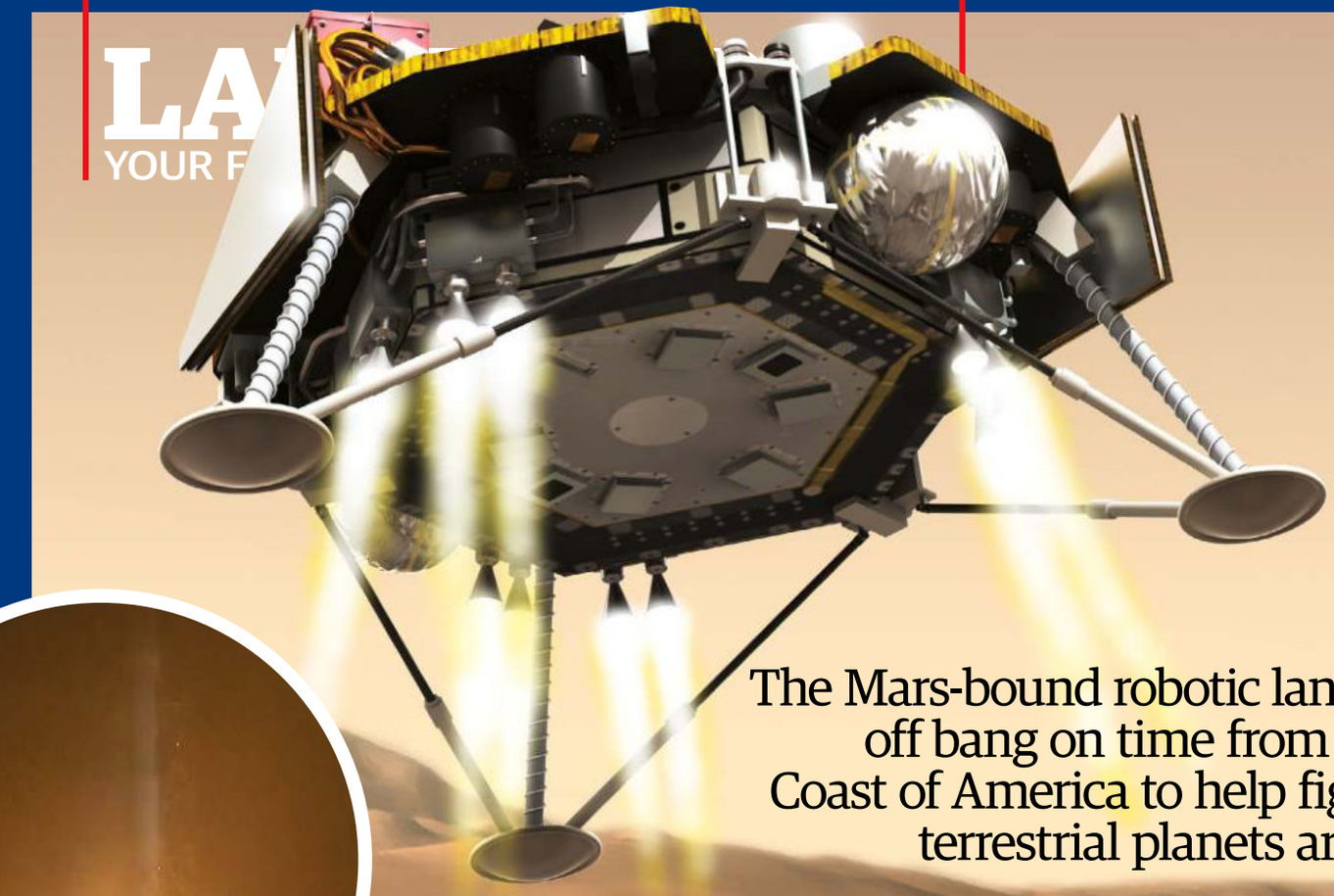


The Mars-bound robotic lander lifted off bang on time from the West Coast of America to help figure how terrestrial planets are formed

NASA launches InSight mission to the Red Planet

Rare pulsar glitch captured for the first time

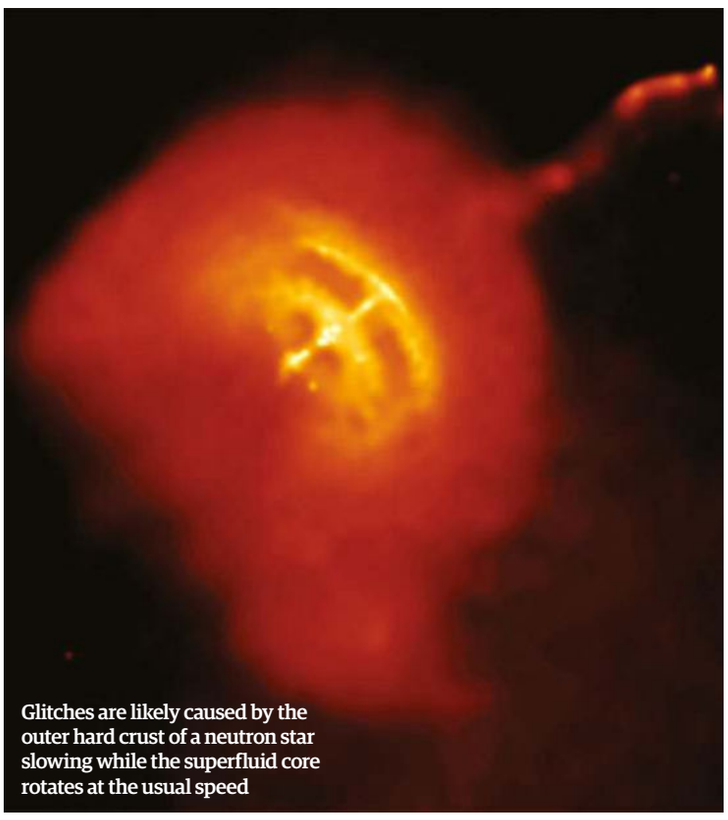
Three years of waiting proved time well spent as a radio telescope finally records the unusual phenomena

Astronomers have captured a rare 'glitch' in a neutron star using a radio telescope for the very first time. The phenomena – referring to the abrupt increase in the rate of a star's rotation – was seen in the Vela Pulsar, which is about 1,000 light years from Earth, and allows astronomers a tantalising glimpse into the inside workings of a neutron star.

The observation follows a three-year hunt to catch the glitch live using the University of Tasmania's 26-metre radio telescope at the Mount Pleasant Observatory and the 30-metre radio telescope at Ceduna, South Australia. It has allowed astronomers to get a better handle on the neutron star's interior dynamics – before the use of radio telescopes scientists were unable to understand what drives the change.

Indeed, Vela Pulsar's glitches were first identified in 1969, but only by collecting huge amounts of data over four years could individual pulses be detected. The glitch and the weak pulses before and after lasted for just five seconds which, lead researcher Jim Palfreyman, says "is on the faster end of the scale than the theorists had predicted". There are now more clues as to how matter behaves at extreme temperatures and pressures.

Neutron stars are remnants of a collapsed star core after it becomes a supernova, while pulsars are highly magnetised neutron stars with a fast spin rate (in this case, 11 rotations per second). "By capturing the glitch, and the individual pulses, it helps us to better understand the 'equation of state' – which is how matter behaves in different environments," Palfreyman adds. "The information gained might be useful in a variety of ways, such as building devices or machines that operate at extreme temperatures and pressures, like a fusion reactor."



Glitches are likely caused by the outer hard crust of a neutron star slowing while the superfluid core rotates at the usual speed

NASA has successfully launched its latest mission to the Red Planet, sending the robotic InSight probe on its long-anticipated six-month journey to discovery. The lander was aboard United Launch Alliance's Atlas V rocket, the biggest available for the 301-million mile voyage, and it lifted-off, as scheduled, from the launch site at Vandenberg Air Force Base in California at 04:05 local time (12:05 British Summer Time) on 5 May. InSight is due to land on an equatorial region Elysium Planitia on 26 November 2018.

Manufactured by Lockheed Martin Space Systems, InSight - Interior Exploration using Seismic Investigations, Geodesy and Heat Transport - was originally due to be launched in March 2016 but an instrument failure caused a two-year delay. With that fixed, however, and no other problems surfacing, everything went as planned although the launch site was blanketed by thick fog. After four minutes, the Atlas booster engine cut off, the boosted separated successfully 11 minutes into the second stage of the flight, the Centaur main engine ignited for the first of its two burns and the payload fairing was then finally jettisoned.

One of the experiments will involve testing the Martian surface using seismometers to feel for tremors that will help scientists better understand how the planet's underground rock is layered. Data from such "Marsquakes" will give an insight - hence the name - into the evolutionary processes of such rocky planets. InSight will also study the rate at which heat escapes from the interior, and scientists will seek to measure small changes in the probe's radio signals to figure the orientation of the planet's polar axis: this will point to the composition, size and density of the core.

Indeed, by the end of the mission scientists will also have a grip on the thickness of Mars' crust and the structure and composition of its mantle. It is the first time seismometers have been sent to Mars since the Viking landers in 1970s but the difference is that those were not placed on the ground and they remained on the body of the probes.

InSight is the twelfth mission of NASA's Discovery program and the mission is due to last for at least two years (or one, if you're counting in Martian terms). "The goal of InSight is nothing less than to better understand the birth of the Earth, the birth of the planet we live on, and we're going to do that by going to Mars," says the mission's principal investigator Bruce Banerdt.

An artist's impression of NASA's InSight mission, which was launched early on 5 May (inset)

© NASA; Adrian Mann

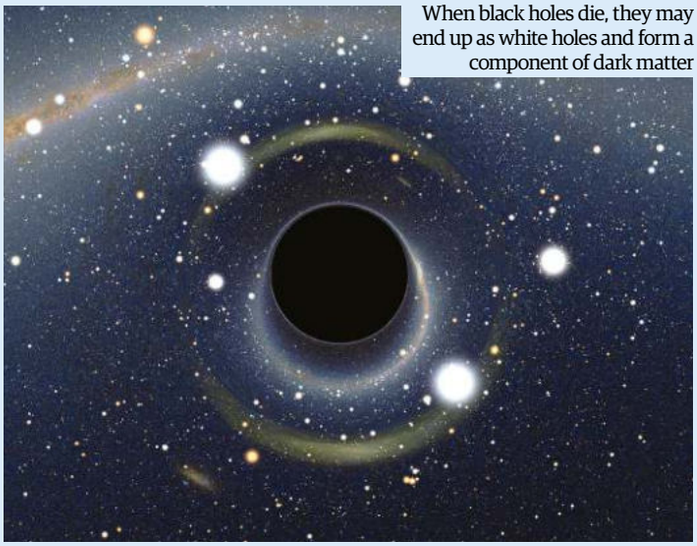
"We have to go to Mars to better understand planet Earth"

White holes could hold the secret of dark matter

'Inverting' black holes may be the key to where the substance could be lurking

A component of dark matter could be formed by remnants of evaporated black holes, according to a new study by two theoretical physicists. Carlo Rovelli and Francesca Vidotto, of Aix-Marseille University in France, have suggested that black holes (which have such a powerful gravitational pull that not even light can avoid them) become white holes (which pose no threat) when they shrink to their very lowest point.

Such an argument goes against the previously held theory that black holes simply disappear. Rovelli says the quantum nature of space-time dictates that black holes are made up of indivisible quantities known as quanta, and so could not just vanish.



When black holes die, they may end up as white holes and form a component of dark matter

© Alain r

The scientists hypothesise that they rebound and, what's more, it is entirely feasible that they have done so within the lifetime of the universe.

Rovelli and Vidotto suggest a white hole would be smaller than a proton and weigh a millionth of a gram, and that one of them would be needed for every 2,400 cubic miles. They would be invisible since they would emit no radiation and be smaller than a wavelength of light, and they may even predate the Big Bang. As if that wasn't mind-bending enough, the scientists are set to carry out further research. They want to see if white holes exist from a previous universe and whether they would explain why time flows only forward in the current one.

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YOUR FIRST CONTACT WITH THE UNIVERSE

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Galactic collision happened 'much earlier' than expected

The smash up took place much more quickly than simulations - or even theories - have previously suggested

Astronomers have observed the beginnings of a massive cosmic collision involving a staggering 14 galaxies – turning assumptions about the way structures form in the universe on their head.

Tim Miller, from Dalhousie University in Canada and Yale University in the US, led a research study which focused on a collection of young starburst galaxies known as SPT2349-56 some 90 per cent of the way across the observable universe.

He found the pileup took place 12.4 billion light years away from Earth, 1.4 billion years after the Big Bang. Since such a colossal galaxy cluster should not have existed back then – the wisdom being that they happened three billion years after the universe began – the observation has been surprising.

"How this assembly of galaxies got so big so fast is a mystery," says Miller, a PhD candidate. "It wasn't built up gradually over billions of years, as astronomers might expect. This discovery provides a great opportunity to study how massive galaxies came together to build enormous galaxy clusters."

The study has been supplemented by research led by Iván Oteo from the University of Edinburgh, which discovered a similar large merger of ten dusty star-forming galaxies. "The lifetime of dusty starbursts is thought to be relatively short because they consume their gas at an extraordinary rate," says Oteo.

"At any time, in any corner of the universe, these galaxies are usually in the minority. So, finding numerous dusty starbursts shining at the same time like this is very puzzling, and something that we still need to understand." The observations were made using the Atacama Large Millimeter/summillimeter Array (ALMA) and the Atacama Pathfinder Experiment (APEX).

Jim Bridenstine is sworn in as NASA administrator

Politician Bridenstine takes his position as the space agency's leader, after being narrowly approved by the US Senate 50-48

Republican congressman Jim Bridenstine has become the next administrator of NASA, filling a post that has been vacant since January 2017. Although Bridenstine, aged 42, has no scientific background, he took office as the 13th administrator and was sworn in by Vice President Mike Pence at the agency headquarters in Washington.

The former Navy pilot also sits on the House Committee that oversees NASA, and he will oversee a staff of 17,000 and a budget of $19 billion. NASA astronauts Scott Tingle, Drew Feustel and Ricky Arnold congratulated him during the swearing-in ceremony while working on board the International Space Station. "NASA represents the best of the United States of America," Bridenstine said. "We lead, we discover, we pioneer and we inspire. I look forward to our journey together."

Following the ceremony, Bridenstine met with senior agency leaders and spoke of the direction that NASA is heading. "The appropriations bill that is now law renews focus on human spaceflight activities and expands our commercial and international partnerships. It also continues our pursuit of cutting-edge science and aeronautics breakthroughs," he said.

© NASA/Bill Ingalls

Vice President Mike Pence swears in Jim Bridenstine as his family watches

© NASA

NASA's only lunar rover has been axed, baffling scientists

Plans to fly the space agency's Resource Prospector mission to the Moon have been unexpectedly cancelled

NASA has scrapped its long-held plans to launch a sophisticated robotic rover to the surface of the Moon. The Resource Protector was due to mine the lunar surface in 2022 ahead of returning astronauts for the first time since 1972.

Instead, the new NASA administrator Jim Bridenstine tweeted that its instruments "will go forward in an expanded lunar surface campaign", and while it's not clear what that actually entails, it appears some of the instruments will be flown on commercial lander missions, with Bridenstine adding: "More landers. More science. More exploration. More prospectors. More commercial partners. Ad astra!"

Despite such promise, scientists have urged Bridenstine to reverse the decision. They believe there is great merit in sending this rover to one of the Moon's polar regions, where it would have excavated and studied water, hydrogen and oxygen while examining lunar ice close up. President Donald Trump has also made it clear, in signing Space Policy Directive 1, that he eventually wants NASA astronauts to land on the Moon which makes the move even more surprising.

Indeed, were it to go ahead, it would see the continued development of a lander and a solar-powered rover fitted with a drill. The hope was that it would further scientific knowledge of the Moon for the benefit of future astronauts and potentially lower launch costs if resources were able to be created on the lunar surface.

It is certainly being seen as a blow for engineers who have spent four years working on the mission. While it was not at the full-funding stage, it was sufficiently advanced. Budgetary issues are believed to be behind the decision, although this is not confirmed.

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			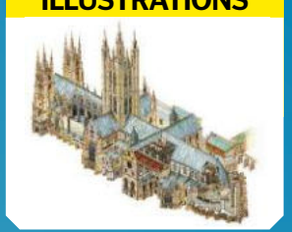	

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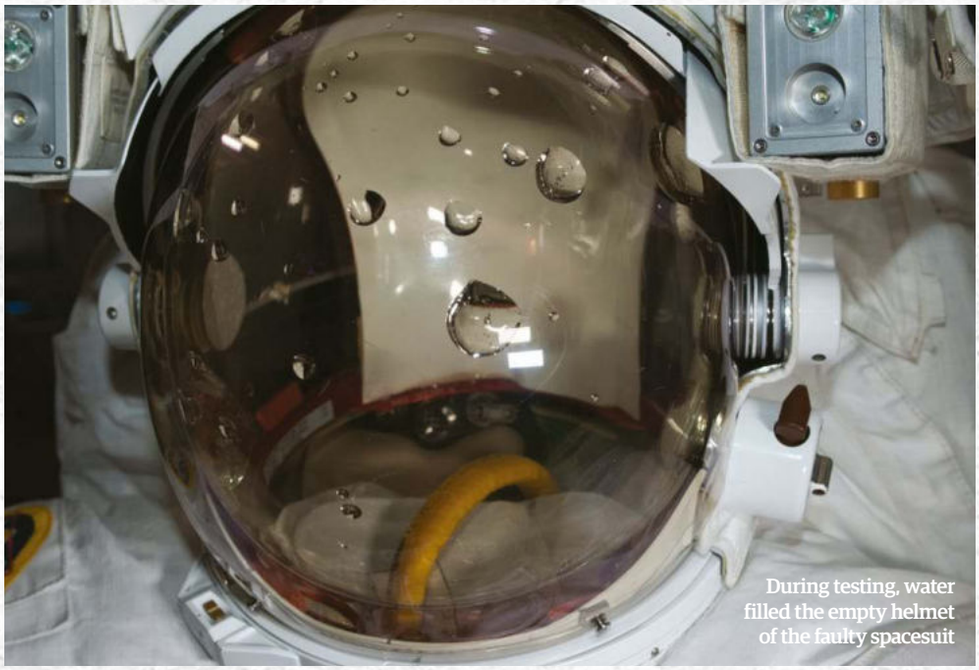
Buzz Aldrin and NASA's finest reveal...

"OUR MOST DANGEROUS MISSIONS"

In space, no one can hear you scream... which is just as well given the numerous things that can go wrong, as Buzz Aldrin, Mike Massimino, Luca Parmitano and other prolific astronauts tell **All About Space**

Space is well-known for its risks. As if the mental pressures of working in an isolated zero-gravity environment weren't enough, astronauts can suffer muscle loss, changes in their eyesight, radiation exposure and fluctuating blood pressure. There have also been catastrophic disasters during take off, problems with landing and mechanical failures that needed to be tackled.

However, one thing's for sure. Astronauts have come to expect the unexpected. For no matter how well prepared they and the ground crews are, and regardless of the millions of man hours that go into designing a mission, unforeseen problems can and do emerge. And when such bad luck rears its ugly head, space really can appear to be the loneliest place in the universe.



© NASA; Kevin McGivern

During testing, water filled the empty helmet of the faulty spacesuit

PART 1 OF 3*

"I was upside down with no light, no eyesight"

Luca Parmitano recalls the moment the helmet of his Extravehicular Mobility Unit suit began filling with water

What happened?

Luca Parmitano's second EVA had to be terminated just 92 minutes into the planned 6.5-hour spacewalk when water leaked into his helmet, putting the Italian engineer and astronaut at risk of drowning. Making it difficult for him to see and hear and hindering his return to the airlock, it was later discovered that one of the suit's filters had become clogged by contamination, which had forced water from the cooling system to back up.

What mission were they on?

Expedition 36/37, working alongside fellow spacewalker Christopher Cassidy in July 2013.

"The unexpected sensation of water at the back of my neck surprised me, and I was in a place where I'd rather not be surprised. I had been out of the International Space Station for around 45 minutes to an hour on my second spacewalk when I felt it and, with superhuman effort, I forced myself to inform Houston, knowing that it could signal the end of the EVA [Extravehicular Activity].

"At the time, Chris [Cassidy] and I had no idea what was happening. At first we were both convinced that it must be drinking water from my flask that had leaked out through the straw, or else it's sweat. But, as we were waiting for advice [from Houston], I realised it wasn't going to get better. I thought the water was too cold to be sweat and, more importantly, I could feel it increasing.

"More water crawled through the back of my head over my communications cap, so we all decided, with concurrence on the ground, that it was time to go back inside and call the ground for a terminate, which is a soft word for stopping an EVA. It means putting everything back in good condition and going back inside – as opposed to an abort, which is when you leave everything as is and you go back inside and depressurise as fast as you can.

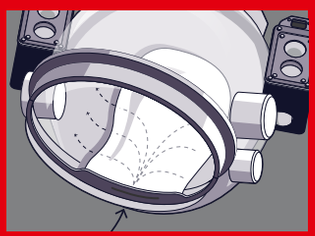
"To get back I had to go to the airlock one way and Chris had to go a different way because of the way we were routed. But, maybe a minute or two later, things began to get interesting, so to speak. I was about halfway to the airlock, becoming more and more certain that the water was increasing. I felt it covering the sponge on my earphones and I wondered whether I would lose audio content.

"Then, with the water almost completely covering the front of my visor, sticking to it and obscuring my vision, the Sun set. To understand what this means,

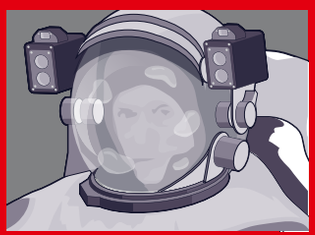
*Catch part 2 in issue 79, on sale 21 June

Parmitano is also a Lieutenant Colonel in the Italian Air Force

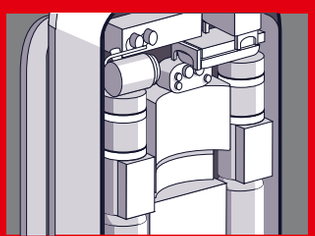
How did the spacesuit helmet leak?



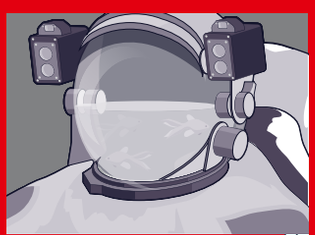
Water seepage
A port on the bottom of a space helmet allows ventilation air to flow behind the astronaut's head and blows the air in front of his or her face.



Building up
When cooling water got into the air port it began to build up, and Luca Parmitano was able to feel water at the back of his head, in his ear cups and over his eyes.



Blockage blamed
It was later found that a blockage in the spacesuit's water separator was to blame. It allowed the water to leak into the vent loop and into the helmet.



Perils of zero gravity
According to investigators, part of the problem was the way water works in zero gravity. Parmitano says it felt like being in a goldfish bowl and he feared drowning.

"I was about halfway to the airlock, becoming more and more certain that the water was increasing" **Luca Parmitano**

you have to imagine an orbital sunset, which is different than Earth. You have light, then you don't. When you don't have light in orbit, it's the absolute absence of light. It's a black like nothing that you can experience when back on Earth.

"The light coming from my helmet could only illuminate a circle of light about 30-centimetres (one-foot) wide. At the same time the water covered my eyes and nose, so I was isolated in the sense that I couldn't really see well enough to navigate my own way back. I was also upside down and I had to manoeuvre myself around a no-touch zone, which is a zone that is either dangerous or you could damage some important equipment.

"So, I was upside down with no light, no eyesight because my eyes were covered. I had water in my nose. I tried to call the ground and Chris, but neither one could hear me due to water or because of the sheer geometry of the station. That's when I had to make a very quick decision either to wait there or try to go back however I could. In a split second I came up with a decision and a plan to move and do whatever I could. I moved and decided to try to use my own capabilities to get back. About five minutes later I was back at the airlock.

"Chris arrived right away and we went inside. Chris closed the hatch and we repressurised. As soon as Karen [Nyberg] started repressurising I couldn't hear anything, so the ground was calling me, Chris was calling me, but I couldn't hear. It was pretty miserable. Water was inside my ears, inside my nose, all over my eyes, so I didn't want to move. The next thing I knew Chris was squeezing my hand trying to get a response and my response was to squeeze as hard as I could to give him the okay.

"After everyone else repressurised they opened the hatch and I saw a very worried group, Fyodor [Yurchikhin] and Karen, who quickly hurried me out of the airlock to take my helmet off, and that was the end of it."

Did you know?
Astronauts Timothy Kopra and Tim Peake had to end their spacewalk on 15 January 2016 when Kopra reported a small water bubble followed by a film of water inside his helmet. It happened after the pair had completed their main task but, as it got bigger, Mission Control decided to terminated the six-hour spacewalk an hour and 50 minutes early. Kopra was roughly 200 feet away from the ISS – about as far as a spacewalker can safely go.

Just over an hour into the spacewalk, Parmitano reported water inside his helmet on the back of his head

Massimino was forced to rip off the handrail that had a stripped screw to continue repairing Hubble

"I'd broken Hubble... and I was alone in space"

Mike Massimino had made a huge error. What's more he didn't have back up while his fellow astronauts looked on

What happened?

Mike Massimino and fellow astronaut Mike Good were completing their eight-hour, two-minute spacewalk where they sought to repair Hubble's imaging spectrograph, an instrument used to detect far-off planets and black holes. More than 100 new space tools were developed for the spacewalk, but Massimino ended up yanking a handrail away with his hands. It had been blocking the access panel to the power supply, but one of the screws was stripped, making it impossible to come off by conventional means. He did this while lapping the Earth at 28,164 kilometres (17,500 miles) per hour.

What mission were they on?

STS-125 Atlantis, the final Hubble servicing mission by the Space Shuttle, between 11 and 24 May 2009.

"We were going to use a large number of tools during a mission to repair the failed power supply of the Hubble Space Telescope, and we had practiced it for years. Although the two bolts on the top of a handrail that covered the access panel came off with no problem, and while a bolt to the left at the bottom also came out easily, the bolt on the bottom right did not. Instead, the head of the bolt was stripped out, and when I took a closer look, I spun my tool inside of it and destroyed any chance of being able to undo that screw.

"This meant the handrail wasn't going to come off and I wasn't going to be able to get to the main electronics board. This meant we were never going to be able to replace the power supply, never get Hubble back running and never find out there was life on other planets, and I was going to be blamed. That was pretty much my thought process, but the team on the ground started to troubleshoot and I started trying not to make things worse in space.

"It took them about an hour or so to come up with a solution - and that time felt like an eternity out there. All the while the Sun's coming up and down and I'm wondering whether sooner or later we're going to have to knock it off and come inside because we were running out of time. But then they told me to get some tape and vice grips: I could understand vice grips because that was a tool. Tape, on the other hand, made me think we were running out of ideas. I didn't even know we had tape out there: were we going from the hardware store to the stationary office supplies now?

"But someone had the idea of just seeing if I could yank this thing off, and they'd worked out that about 60 pounds of force was required. So I did just that, grabbing some tape from the toolbox at the front of the space shuttle before heading back to use it on the bottom of the handrail. I felt a deep loneliness because there was no one to help me at that specific time, but I taped the handrail, put my hand on it and knew that the reason I was using that tape was because there would be a real worry if any debris got loose. So I pulled.

"I managed to rip the handrail away; got it right off. I could then get to the access panel, but my power tool's battery had gone and I was also needing an oxygen refill. I put my fears aside, got more oxygen and swapped out the battery before getting on with the task. The screws came out, the new power supply went in and it worked - a successful mission from a position higher than the Space Station - and the instrument had come back to life. I then just looked at the Earth from 350 miles [563 kilometres] up.

"I was out there in space, all by myself, with my own life support system, and I could look anywhere I wanted. I could look and see the planet from where Hubble is. I thought, this would be the view from heaven. But then, I thought, it was more beautiful than that. It was like looking into a paradise. The brightness of the Sun when you leave the atmosphere, it's like, wow! There it is! It looks just like a star. And it's bright, really bright! It's the brightest bright I've ever experienced. Getting to see the planet and the stars on a spacewalk was truly an incredible experience."

"The tether loss was like getting hit in the stomach"

When a satellite remained inert after deployment, Jeffrey Hoffman had to perform an unplanned, untested spacewalk

What Happened?

When the communication satellite Syncom IV-3 failed to activate it meant Jeff Hoffman and David Griggs were called on to perform an EVA, even though the task was something they had never done before. There was also a potential danger of the rocket engine going off.

What mission were they on?

STS-51-D between 12 and 19 April 1985, with the 16th Space Shuttle flight also suffering a ruptured tyre and brake damage on landing.

"Before every shuttle mission, two crew members were trained to use spacesuits. This meant I knew what I was doing as far as the spacesuit was concerned, but because it was the early days of the shuttle, flights kept getting postponed and cancelled. Before we actually flew in April 1985, we had been assigned to four different flights, each of which had different EVA requirements.

"Still, in my mind, if you were basically comfortable working with tools then you could go into a workshop and build something you've never built before. So while I was aware of the dangers (any time you put on a spacesuit and go outside you are in a more vulnerable situation than when you're inside your spacecraft), when the satellite did not activate on our mission and we realised we were going to have to put on a spacesuit and go outside, my general feeling was of excitement.

"Of course, you always know that something can go wrong with your spacesuit. You could also get hit by a piece of space debris. But we needed to try and sort the problem. It was definitely what we call a sporty proposition: if someone had suggested before the launch that somebody was going to go up there and do this, it may have been hard to get it approved just because it was so far out of the ordinary.

"But when we reported that the antenna did not pop up (it is supposed to do so two minutes after it is deployed), we knew that NASA was generally willing to pull out all the stops in order to fix a problem, and we had to work out why something had gone wrong. Either the antenna was stuck and the sequence was going as planned – which meant that in 45 minutes the rocket motors were going to fire – or the satellite never turned on.

"We didn't know which, so just for safety we moved away from the satellite. When it didn't fire 45 minutes later we knew that the whole ignition sequence was somehow blocked. The only single-point failure was a switch on the outside of the satellite which is depressed when it's in the cargo bay but opens up when deployed. It was really the only thing that we had access to because we were not planning to do a spacewalk, so we didn't have any special tools. We didn't even have any foot restraints where we could lock ourselves into a position.

"The idea of trying to go inside the satellite to do anything was out of the question, so we set out to access that switch. At first, the idea was to go on the end of the arm, hold on with one hand, fly up to the satellite and flick the switch with my other hand. That was a bit too sporty. So instead they made these two tools, which we attached to the end of the robotic arm. Our job on the EVA was to attach those tools to the end of the arm.

"We attempted this the next day, performing the rendezvous and flying up to the satellite to operate the arm that flicked that switch. It was something that nobody had ever practiced beforehand, but we just did it. Had we seen that antenna pop up then we would have known everything was okay and we would have gotten out of there in a hurry, but it never happened. We were not able to fix the problem, but we demonstrated that the switch was not the failure, so about three or four months later another crew went up, deployed their two satellites, flew to the satellite we worked on and used special equipment and foot restraints to capture it, lock it down into the cargo bay and basically hotwire the ignition circuit so that it could then be commanded from the ground.

"After they did that, they closed it up and threw it back into orbit before flying away. The ground then commanded the ignition sequence to start and the satellite went up to geostationary orbit, where it began working just fine. But our job was important. Had we not attempted to fix the obvious problem, the second crew would have been sent up to do it and it wouldn't have worked. It was a great story in the end."

Did you know?

The first spacewalk was performed by Soviet cosmonaut Alexei Leonov on 18 March 1965, but it was far from smooth flying. In the vacuum of space his spacesuit ballooned, which would prevent him from re-entering the spacecraft. Running out of time, he decided to bleed off some of the suit's pressure, risking oxygen starvation. Later on, a malfunction caused oxygen levels to soar inside the craft, increasing the possibility of a fire.

Hoffman was involved in Hubble's first servicing mission in 1993 to repair its optics

Did you know?
During Expedition 10, Chiao became the first astronaut to vote in a US Presidential election from space.

"We could have killed everyone aboard the ISS"

Leroy Chiao found himself heading at an increasing speed towards the International Space Station

What Happened?

NASA astronaut Leroy Chiao and cosmonaut Salizhan Sharipov had been nearing the end of their flight to the International Space Station (ISS) when the autopilot hit a problem and began to speed up rather than slow down. With danger imminent, they had to start thinking fast.

What mission were they on?

Expedition 10, which was the tenth expedition to the ISS.

"On my last mission we were flying to the ISS in a Russian Soyuz spacecraft, TMA-5. It was Expedition 10 which began on 16 October 2004 and I was the commander and NASA science officer, flying with flight engineer Salizhan Sharipov to relieve the crewmates from the previous expedition. We were due to remain in space until 24 April 2005 – a timescale of 192 days, 19 hours and two minutes from launch to landing. It was quite a ride, and very different from the space shuttle.

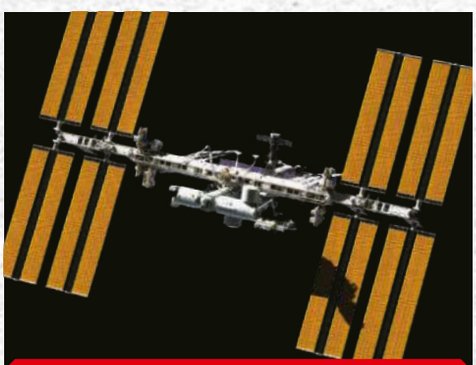
"As we were approaching the ISS, the alarms started sounding with just under 200 metres [656 feet] to go. We couldn't believe it. Instead of slowing us down, the autopilot was speeding us up as we approached the station. Simultaneously it was rotating us to the left, so we were starting to lose visual sight of the ISS.

"We swung into action – we already had our emergency books in our laps – and we executed the procedure to take manual control away from the autopilot. I punched in the necessary commands while Salizhan took the hand controllers and fired braking pulses while correcting the rotation. We got the ship stopped 50 metres (164 feet) from the station, much to our relief.

"While this was going on there had been excited conversation in our headsets as the ground struggled to catch up with us. They asked us to put the ship back into autopilot. Salizhan and I looked at each other. Salizhan then asked them: "Why would we do that?" The answer was that they felt there should be no problem. Reluctantly, we re-engaged the autopilot.

"Immediately the alarms sounded again and our troubles started over. Without stopping to say anything, I took the ship back into manual mode. Salizhan and I shared another look, and we both nodded. It was understood between us that we wouldn't do that again, even if the ground demanded it.

"We then executed the first manual night docking to the ISS. After we were safely docked, I took a deep breath. The hairs on the back of my neck suddenly stood up and I began to shiver. It was then that I realised that this had been a very dangerous situation. If we had collided with the International Space Station, then we almost certainly would have been killed. Not only that, we could have killed everyone aboard the ISS too."



Good vibrations: how Chiao shook the ISS

When a solar array was left half-exposed and in mid-retraction above the International Space Station in 2006, mission controllers turned to a method that had been inadvertently developed by Leroy Chiao two years earlier.

Believing friction between the P6 array's guide wires was to blame, they reckoned getting an astronaut to go through a vigorous exercise workout could relieve the tension and allow the array to fold up properly. Why? Because Chiao had shook the space station a couple of years earlier by doing the exact same thing.

"I was doing squats on the Interim Resistance Excercise Device (IRED) and accidentally hit the resonant frequency of the station (about 1Hz)," he says. "The entire stack started shaking, and Salizhan reported that he could see the modules flex as he looked down the centerline from the Service Module."

Although Mission Control had told him to "knock it off" at the time, German ESA astronaut Thomas Reiter was asked to perform 30 seconds of robust exercise on the IRED bungee bar. It took a spacewalk to finally retract the array, but it was certainly a novel potential solution.

"The fuel tank was running low. Then there was a problem with the hatch"

Buzz Aldrin and fellow astronaut Neil Armstrong were seconds away from crashing into the Moon – and worried they wouldn't get home

What Happened?

As Neil Armstrong and Buzz Aldrin looked to land the lunar module Eagle on the Moon, leaving Michael Collins in the command module, they found they were landing miles west of their target site, running out of fuel and desperate to touch down. With the computer about to put them in an area strewn with boulders, manual action had to be taken. Later, they discovered a vital component had accidentally been damaged.

What mission were they on?

Apollo 11, the mission that landed the first two humans on the Moon, on 20 July 1969.

Apollo 11 was the fifth manned mission of the Apollo program

"About four minutes into the landing sequence of Apollo 11, the display on the computer read 1201 and 1202. They were error codes, the number of the alarm, and whatever information was displayed before – whether it was velocity or movement over the ground – was not there any more.

"These codes were disturbing and distracting, but Mission Control didn't know what the alarms meant either. Neil Armstrong, who was paying more attention than I was since he was looking out of the window, took manual control. There were craters drifting by, but not many of them were identifiable. Neil said he thought we may be a little long: the Eagle had overshot its planned landing site.

"The fuel tank was running low and Neil understood this. By experience, there were two minutes of fuel remaining and ahead was a crater that looked dangerous with giant rocks around it. The easiest thing to do was just slow the rate of descent and fly over whatever it was, but that would take longer and burn more fuel and make fuel quantity at touchdown a little less. We were just over 30 metres (100 feet) from the surface, and Neil had to land somewhere.

"I could see the shadow getting bigger because the Sun was behind us, and we were getting closer and closer to the shadow of the lander. The dust began kicking up and, without trying to disturb Neil's concentration, I gave him a little body language to get on the ground as soon as possible. And then it happened. We touched down safely in the Sea of Tranquillity. There had been just 15 seconds of fuel spare.

"We then had a problem with the hatch. The pressure inside had to be low, but when we tried to pull the hatch down it wouldn't come open. I bent the door back and equalised the pressure. I watched out the window to see Neil go down the ladder. When it was my turn to back out, I remember the checklist said to reach back carefully and close the hatch, being careful not to lock it. It would have been very difficult to open it from the outside if I had.

"The Moon's surface can be best described as utter desolation, with no signs of life whatsoever. There were a few hours to collect precious rock samples and carry out experiments. Once we were ready, I looked around at some of the lunar dust on the ground and saw the broken end of a circuit breaker. One of the spacesuits had knocked it out, but it was needed to start the engine and get us back home. The broken parts that were still on the inside had to be pushed in, and only two people could fix this.

"So, in the countdown procedure, I used a pen to push the circuit breaker in. This worked and the engine started. We could go home."

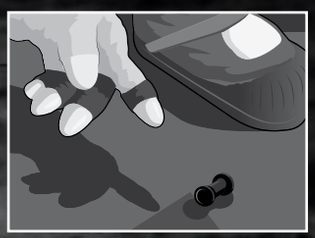
© NASA; Ed Crooks

Communion on the Moon

Before Neil Armstrong set foot on the Moon and uttered his legendary words on 20 July 1969, Buzz Aldrin had opened a plastic container of wine and bread which he had obtained from Webster Presbyterian Church near Houston. He opened up communication with NASA and requested a few moments of contemplative silence before eating and drinking. "It was interesting to think that the very first liquid ever poured on the Moon, and the first food eaten there, were communion elements," he explained. This act was not broadcast, however, and NASA sought not to reveal the news because there was a danger of inflaming atheist Madalyn Murray O'Hair, who had already become incensed that the Apollo 8 crew had read the Genesis creation account and filed a lawsuit.

© NASA;

How to get off the Moon with a pen



Identify the problem

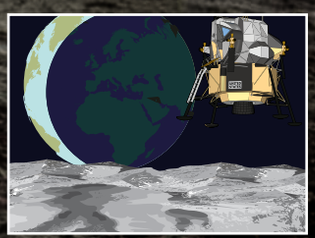
Make some final checks of your cramped spacecraft. Perhaps the bulky spacesuits have brushed too harshly against the switch to the circuit breaker, snapping it.

Figure out its severity

Now look at the circuit breaker in closer detail. This activates the ascent engine and needs to be pushed in. Can that be achieved? Consider how it can be done.

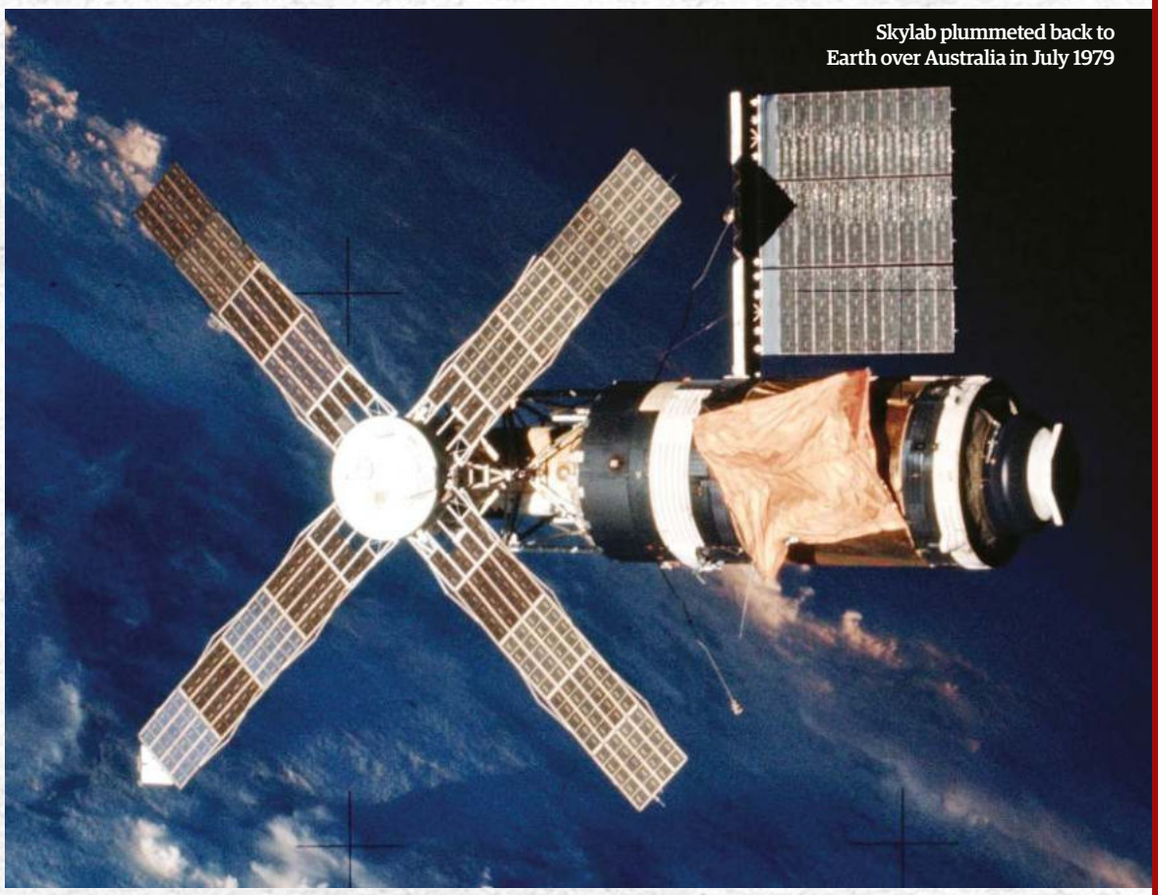
Use that pen

Stop chewing on that felt pen while you think. Maybe it can be used in some way. Just make sure it does not have metal on the end; you're dealing with electrics.



Insert the pen

Put the chrome-bodied pen into the small opening where the circuit breaker should be. Now push and, with a bit of luck, the circuit breaker will hold. Time to get going.



Skylab plummeted back to Earth over Australia in July 1979

"We both went ass over teakettle into outer space"

After fixing a solar array it suddenly deployed, throwing Joseph Kerwin and Pete Conrad off the Skylab hull

What Happened?

After Pete Conrad and Joseph Kerwin had attempted to free a stuck solar array by tugging at it with a hooked pole, a second EVA was sanctioned and proved more successful. But not before the solar array deployed and knocked the pair into space. Could their safety tethers hold?

What mission were they on?

Skylab 2, which launched on 25 May 1973 and was the first manned mission to the first US orbital space station, Skylab.

Kerwin was the first physician selected for astronaut training

"The Skylab space station orbited the Earth from 1973 to 1979 and it had a workshop, a solar observatory, a multiple docking adapter and the ability to allow three crews to stay for up to 84 days in space. But after it launched, a solar array became stuck in the wrong position. It also appeared that the meteoroid protective shield had prematurely deployed, too.

"For that reason the launch of Skylab 2, with myself, Charles Conrad and Paul Weitz, had to be postponed. But we spent the time practicing using special tools that would remove the material jamming the solar array so that Skylab would gain the necessary electrical power. The actual act would mean us performing an EVA to free, and that was always going to be dangerous.

"There were no handholds, no footholds, no visual aids and no lights because there was never any planned maintenance on Skylab. But, because there was a planned EVA to retrieve film and exchange film in the Apollo Telescope Mount, we had the suits, we had the umbilicals and we brought up some tools that we thought we'd need.

"We launched the mission on 25 May 1973. A new solar shield was deployed and then the

Kerwin removes metal from the solar array to allow Skylab's solar panels to fully deploy

spacewalk to free the jammed solar array began. I cut the metal that had jammed the solar wing in a folder position and we'd attempted to use a 7.5-metre (25-foot) pole with a cable cutter on the end of it and some rope to force the array beam to deploy. But getting the jaws on to the strap at a six-metre (20-foot) distance with a pole and no foot restraints was proving impossible so, after sitting around thinking about it, we decided to use an eyebolt we'd found on the surface of the workshop near one of the antennas.

"We didn't know what the eye bolt was there for, but the plan was to strap myself to it. So we got the spare tether, and there was a hook on the front of the suit. I hooked it through there, ran it through the eye bolt, back up through the suit, tightened it up and now I had a three-point suspension. I could stand. I could place my feet on the surface of the workshop and almost straighten my knees all the way out and suddenly I'm as stable as a rock. It was wonderful. Two minutes later the job was done, but as we crawled under the rope that Pete had laid out and stood up, suddenly it released on us.

"We both went ass over teakettle into outer space, but our EVA system was an umbilical, a nice stout umbilical with an eighth-inch [three millimetre] steel cable in the middle of it, so we didn't have any worries about that. We went out to the end of our umbilicals, and then hand-over-handed ourselves back until we got something to hang on to. Turned around, and the prettiest sight I've ever seen in my life was that solar panel cover fully deployed, and you could see the panels starting to come out as they warmed up in the Sun. And we knew we had done the job."

Did you know?

The crew of Apollo 13 — Fred Haise, Jack Swigert and Jim Lovell — currently hold the record for the farthest distance reached from Earth by humans. Scheduled to be NASA's third manned Moon mission, the crew were forced to abort when an oxygen tank exploded, crippling the spacecraft and threatening the lives of its crew. They reached the far side of the Moon — a distance of 400,171 kilometres (248,655 miles) from Earth in April 1970.

How did it happen?

1 Forming a plan
Backup commander Rusty Schweickart directed a plan to release the jammed solar array. It involved Charles Conrad and Joseph Kerwin creating a handrail at the forward end of Skylab.

2 Connecting a rope
The idea was to connect the hooks on the end of a nylon rope to the cover of the solar array and the other to the airlock. Once securely fastened, Kerwin told ground control all was good.

3 Attaching a cable cutter
To do this, an eight-metre (26-feet) cable cutter needed to be attached to debris, allowing them to reach the array and cut the restraining metal strap, then break a frozen hydraulic damper.

4 Ready to pull
When Kerwin pulled nothing happened, so Conrad went to investigate. As he did and reached the cutter end, the jaws snapped. Some of the metal strap was freed.

5 Being thrown off
As this happened, it sent Conrad and Kerwin flying into space. They were saved by their own tethers, but it would have caused their hearts to beat like never before.

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			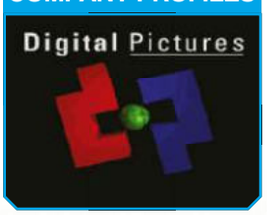	

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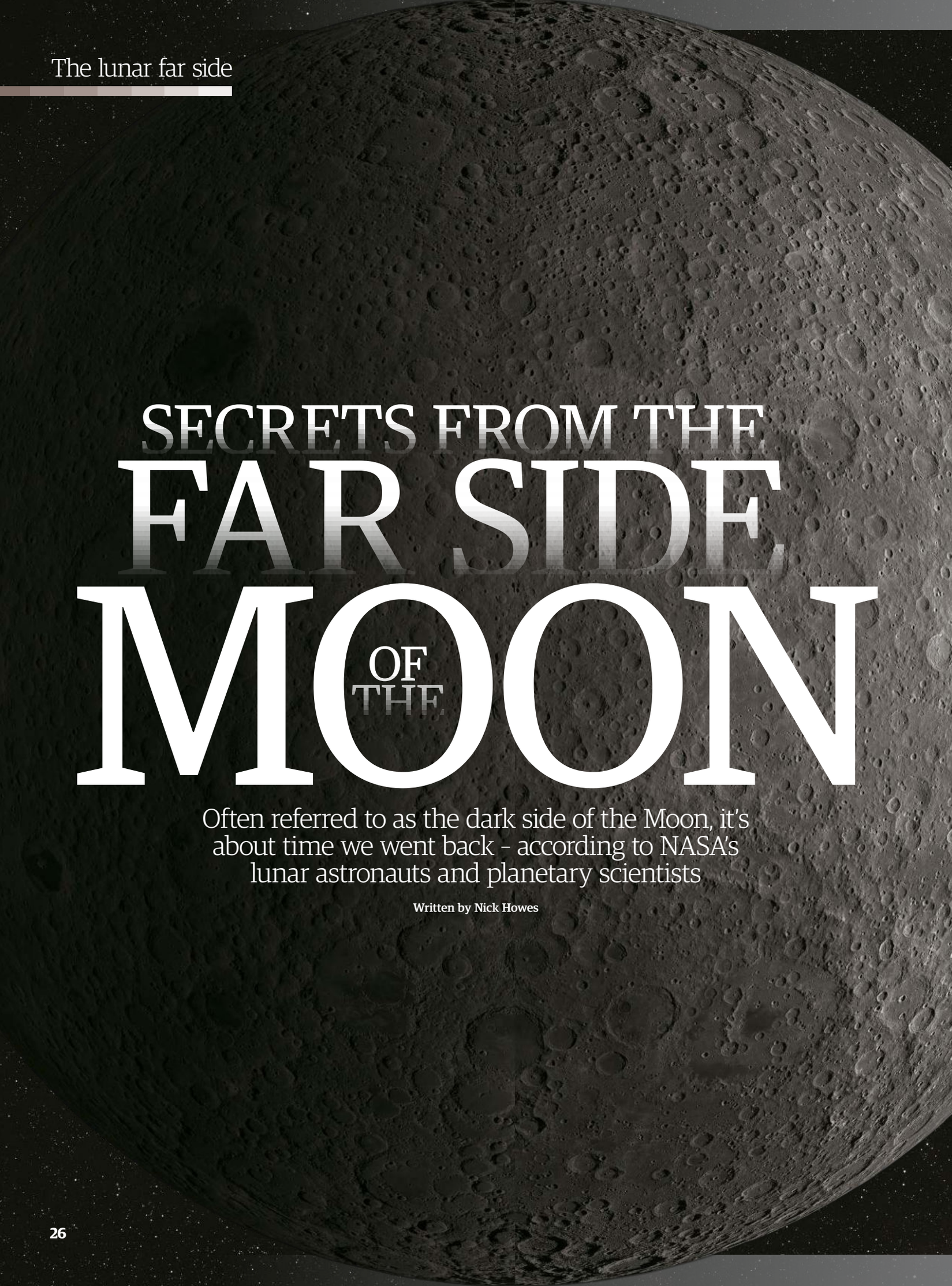


SECRETS FROM THE FAR SIDE OF THE MOON

Often referred to as the dark side of the Moon, it's about time we went back – according to NASA's lunar astronauts and planetary scientists

Written by Nick Howes

Timeline

1959
Lunar 3 spacecraft takes the first photograph of the lunar far side

1962
NASA's Ranger 4 space probe becomes the first spacecraft to impact the far side of the Moon

1965
Soviet probe Zond 3 transits 25 pictures of the lunar far side

1966 to 1967
Lunar Orbiter program provides majority of coverage of lunar far side

1967
Prominent impact basin Mare Orientale photographed by Luna Orbiter 4

1968
Apollo 8 astronauts see the lunar far side for the first time

The Moon shows us its smiling "Man in the Moon" face every month, illuminated by the Sun to varying degrees over the course of its orbit around us. However, thanks to its orbital dynamics, we only ever get to see that one hemisphere from Earth. The other hemisphere – the 'far side' - is constantly concealed from us.

Well, that's not strictly true. Libration, which is the gentle 'wobbling' of the Moon in the sky caused by changes in its position in tis elliptical (i.e. non-circular) orbit around Earth, mean we can catch glimpses of small slivers of the far side - we can actually see 59 per cent of the Moon's surface from Earth at different times of the year. But until the first space missions to the Moon flew around our natural satellite, what lay beyond on the far side was a mystery.

It's often mistakenly thought that the far side of the Moon is in darkness. Rather, it experiences day/night cycles just like the near side. When we see half of the Moon being illuminated by the Sun, giving it a half or crescent shape in the sky, half of the Moon on the far side is being illuminated at the same time. When the Moon is new, the far side is in full daylight instead. When the Moon is full, it's night-time on the far side.

The reason we only see the one face is because of a phenomenon known as 'tidal locking'. The Moon rotates on its axis roughly once every 27 days, which is the same amount of time it takes to orbit the Earth. This means it is rotating at a rate that means we always see the same face, more or less, as it moves around Earth.

Cernan, Young and Stafford on board Apollo 10

"There are two weeks of daylight and two weeks of night on every spot on the lunar surface," Charlie Duke, who was the Lunar Module pilot on the Apollo 16 mission, told **All About Space**. "It was early morning during the Moon day at the Apollo 16 landing site, which was called Descartes. We were the fifth mission to land on the Moon and I can say that it really is a dramatic place."

Our first glimpse of the mysterious far side came early in the space race, courtesy of the Soviet Union's Luna 3 spacecraft almost 60 years ago. In 1959, barely two years after placing Sputnik 1 in orbit, Russian engineers managed to send the spacecraft, which was rude by today's standards, into orbit around the Moon and, for the first time, we got a good look at the mysterious far side.

Luna 3 took film images of the far side in total, which were photographically developed, fixed and

> "There are two weeks of daylight and two weeks of night on every spot of the lunar surface. It's a dramatic place" **Charlie Duke**

Apollo Capsule program manager George Low (left) alongside Wernher Von Braunm, the designer of the Saturn V

©NASA

dried on board - remember, this was long before multi mega-pixel cameras. Ironically, the film used had been stolen from American spy balloons, as it had to be sturdy and radiation hardened.

The spacecraft, using a combination of two camera systems, one wide field and one narrow-field but higher resolution, and a crude on board scanner, could then send transmit the processed images, which were spot scanned from the photographs, back to the receiving station in the former Soviet Union. Although only 17 of the 29 taken were transmitted successfully back to Earth, of which 6 were considered good enough for publication, they proved to be a revelation.

Those 6 images covered 70% of the far side and opened a whole new perspective on the lunar surface. It was almost immediately evident that the dark patches that make the face of the Man in the Moon on the near side, are almost completely absent on the far side. These dark patches are basaltic plains called "mare" created by volcanic activity on the Moon billions of years ago. Instead, the far side was littered with craters, even more so than the near side, and some of those craters were the size of small countries. The Soviets started naming many of the features they were seeing for the first time, an act which caused some controversy in what was known as the height of the Cold War era.

We already had an inkling of one of those vast new craters, which is actually one of the very few mare on the far side. The subtlest hint of Mare Orientale, one of the largest impact craters known, seen on the limb of the Moon, had been known of since it's "discovery" by Julius Franz in 1906 and can be seen during good librations when that portion of the Moon swings around towards us.

The view from Luna 3 showed how vast an impact crater Orientale was, resembling a bull's eye. It was almost 900 kilometres (560 miles) across, pretty much the length of the UK give or take, and was caused by the impact of an asteroid impact, thought to be around 64 kilometres (40 miles) wide just under 4 billion years ago, and the resulting giant crater, termed an "impact basin" was subsequently filled with volcanic lava.

In 1965 another Soviet mission, Zond 3, flew by the Moon with a far better camera than Luna 3 possessed and with the ability to conduct more detailed science observations, including spectroscopy. Zond 3 produced 23 very detailed photographs of the lunar far side, which enabled one of the first detailed maps of the entire lunar surface to be constructed.

In the meantime, NASA were progressing their Apollo Program at a phenomenal rate. Following the declaration by President Kennedy that they would place a man on the Moon and return him safely to the Earth by the end of the 1960s, by December 1968 NASA were ready to send three people - Frank Borman, Jim Lovell, and Bill Anders - all the way around the Moon and back for the Apollo 8 mission. They became the first humans in history, not only to escape from low Earth orbit, but to see the elusive far side.

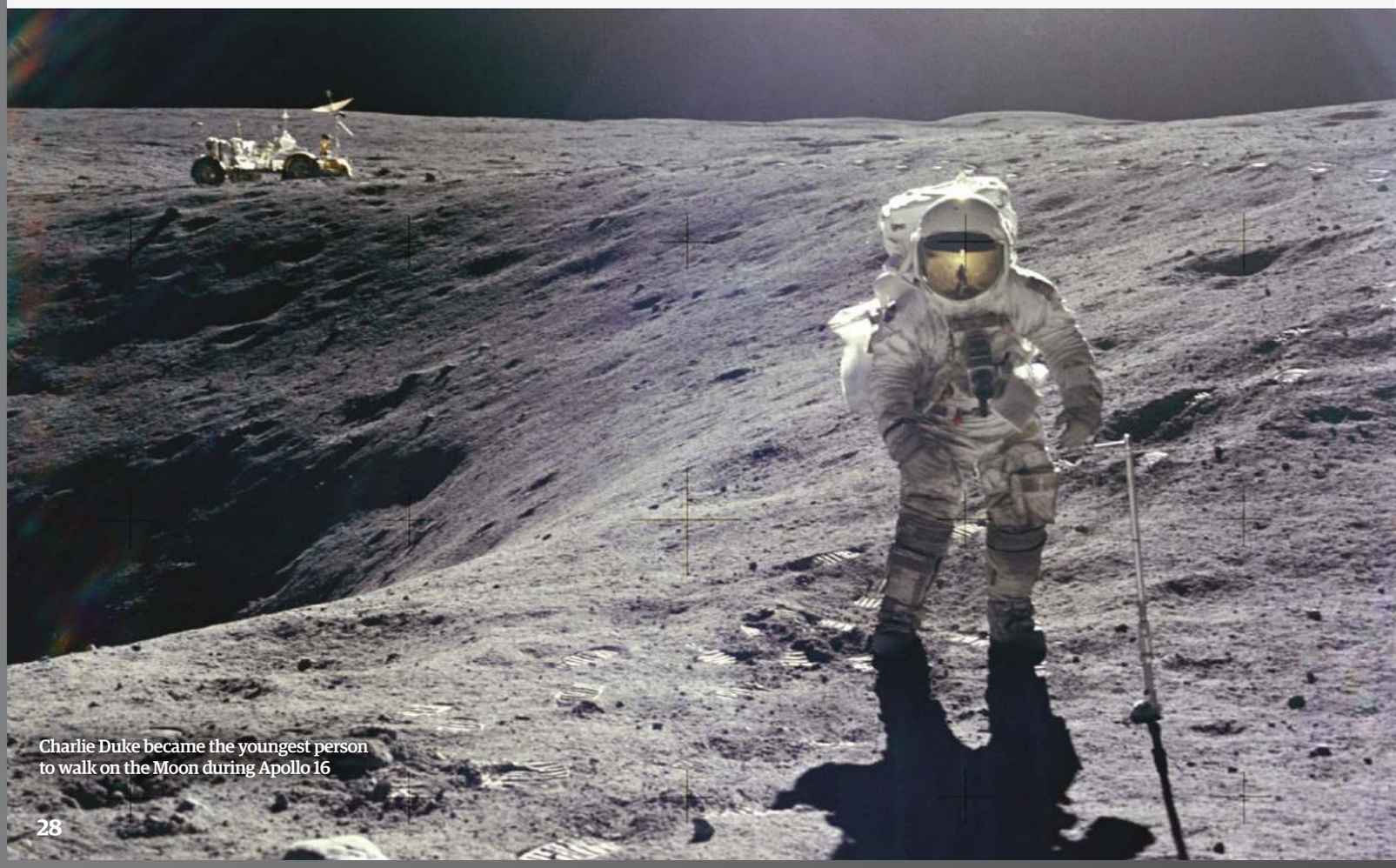
This is how Lovell famously described the lunar surface: "The Moon is essentially grey, no colour, looks like plaster of Paris or sort of a greyish beach sand. We can see quite a bit of detail. There's not as much contrast between that and the surrounding craters. The craters are all rounded off. There's quite a few of them, some of them are newer. Many of them look like—especially the round ones — look like [they were] hit by meteorites or projectiles of some sort"

When their spacecraft flew around the far side of the Moon, the signal to Earth was cut off for around 10 minutes. This loss of signal was a daunting time for the flight crew and mission control, alone and truly cut off from Earth, venturing where no human had ever gone before. As they came back around from the far side, a collective sigh of relief was breathed by many of the flight team at Mission Control in Houston.

Charlie Duke describes what it was like to be flying over the far side of the Moon.

"The computer told us that we were out of contact with the Earth and that we had loss of

"The computer told us that we were out of contact with the Earth and that we had loss of signal" **Charlie Duke**



Charlie Duke became the youngest person to walk on the Moon during Apollo 16

Two sides to the Moon

We can't see the far side from Earth, but the lunar faces are impressively different

Lunar plains
Visible with the naked eye, maria - latin for 'seas' - are visible. They are soldified pools of ancient lava.

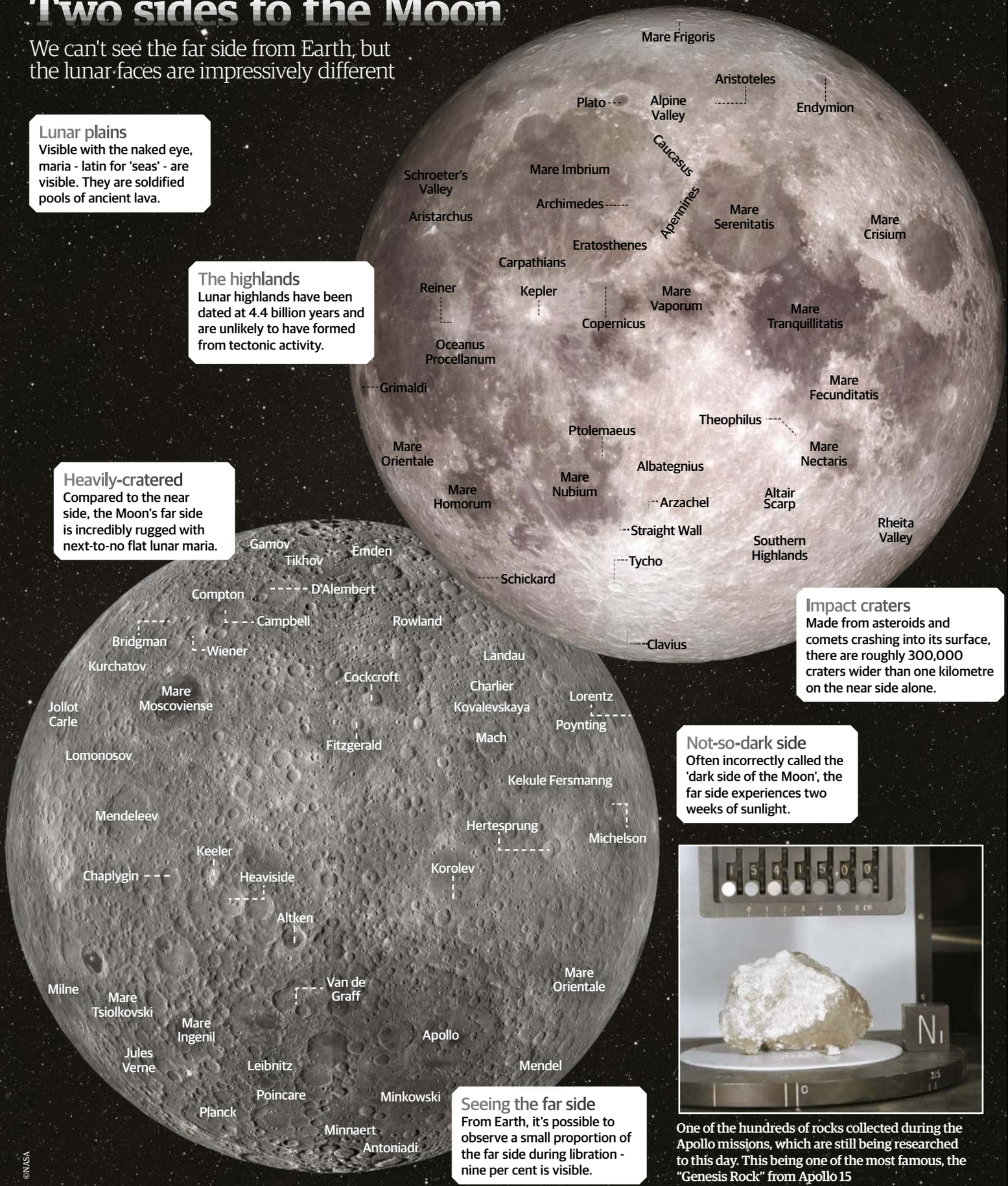
The highlands
Lunar highlands have been dated at 4.4 billion years and are unlikely to have formed from tectonic activity.

Heavily-cratered
Compared to the near side, the Moon's far side is incredibly rugged with next-to-no flat lunar maria.

Impact craters
Made from asteroids and comets crashing into its surface, there are roughly 300,000 craters wider than one kilometre on the near side alone.

Not-so-dark side
Often incorrectly called the 'dark side of the Moon', the far side experiences two weeks of sunlight.

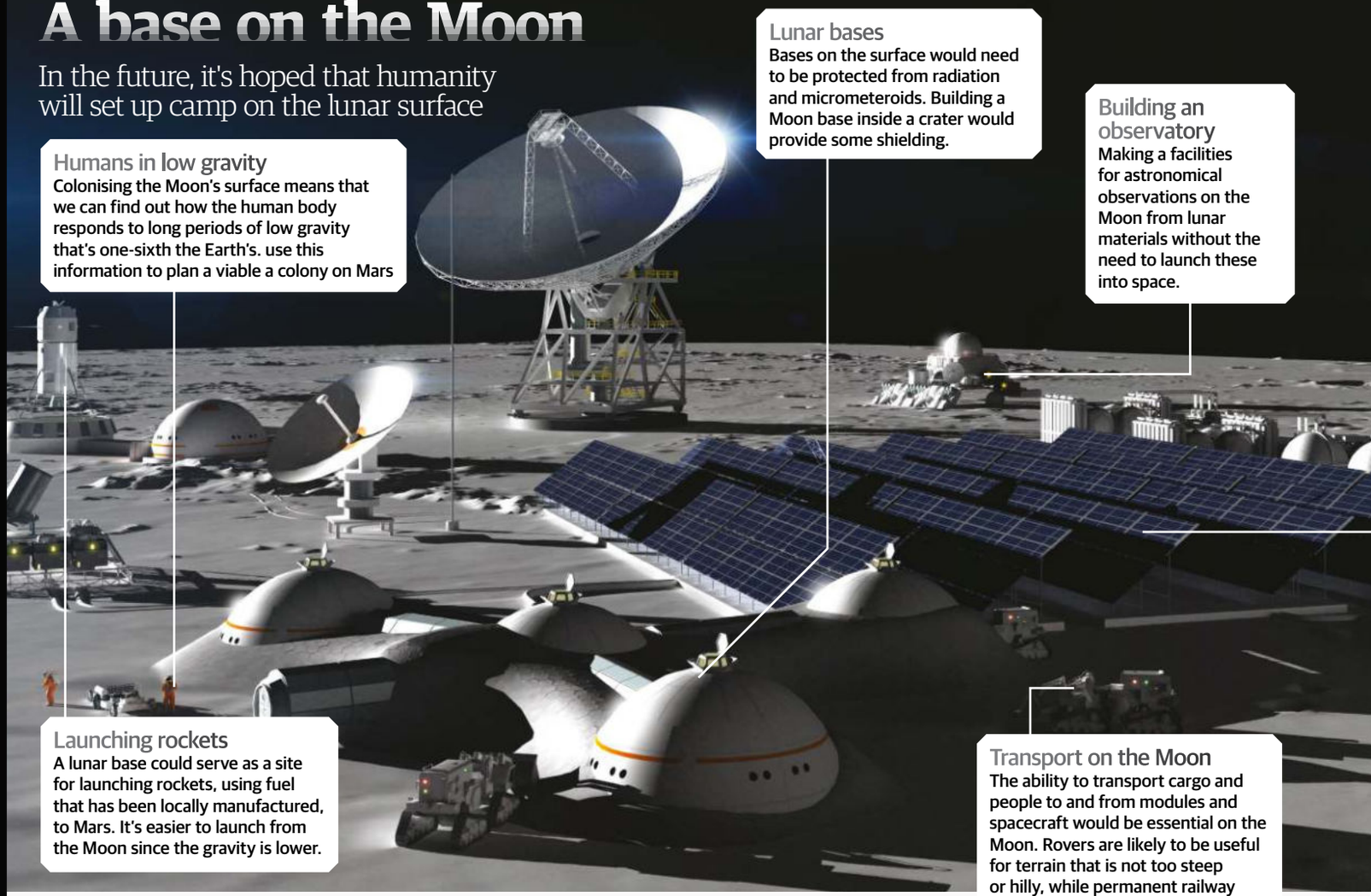
Seeing the far side
From Earth, it's possible to observe a small proportion of the far side during libration - nine per cent is visible.



One of the hundreds of rocks collected during the Apollo missions, which are still being researched to this day. This being one of the most famous, the "Genesis Rock" from Apollo 15

A base on the Moon

In the future, it's hoped that humanity will set up camp on the lunar surface



Humans in low gravity
Colonising the Moon's surface means that we can find out how the human body responds to long periods of low gravity that's one-sixth the Earth's. use this information to plan a viable a colony on Mars

Lunar bases
Bases on the surface would need to be protected from radiation and micrometeroids. Building a Moon base inside a crater would provide some shielding.

Building an observatory
Making a facilities for astronomical observations on the Moon from lunar materials without the need to launch these into space.

Launching rockets
A lunar base could serve as a site for launching rockets, using fuel that has been locally manufactured, to Mars. It's easier to launch from the Moon since the gravity is lower.

Transport on the Moon
The ability to transport cargo and people to and from modules and spacecraft would be essential on the Moon. Rovers are likely to be useful for terrain that is not too steep or hilly, while permanent railway systems could be used to link multiple bases and flying vehicles for-hard-to-reach areas.

signal," he says. "Then, all of a sudden, there was the sunrise, it was the most dramatic sunrise I've ever seen.In Earth orbit, you see the Sun's glow on the horizon or the planet's atmosphere and it gets brighter and brighter. The Moon is different though - there's instant sunlight with long shadows on the lunar surface. The far side of the Moon was very rough back there. I would not have wanted to land on the backside of the Moon."

After the success of Apollo 8, Apollo 9 went back in to vital low Earth orbital testing of the lunar module, so the next astronauts to visit the far side were Gene Cernan, John Young and Tom Stafford on board Apollo 10 in May 1969, just two months before the historic landing of Apollo 11.

However, while flying over the far side of the Moon, the trio of astronauts encountered something strange, which in the last few years NASA has been forced to re-explain thanks to conspiracy theory documentaries airing on U.S television. The facts had been well known since the 1970s.

These "strange events" on Apollo 10 were manifest in the form of some very odd sounds. The radio system on board the Apollo spacecraft were crude by modern standards, though state of the art at the time. The command and lunar modules were relatively noisy environments according to most of the astronauts, with bumps and bangs combined with the whirring of fans and engine noise. What the Apollo 10 crew heard through the radio systems baffled them. They described it as being almost like that made by an electronic instrument called a Theremin, often used in creepy science fiction B-movies of the 1950s and 60s, as well as on the Beach Boys song "Good Vibrations". Research has since proven that the sound was nothing more than an interference effect from those 1960s radio communications systems on board.

With the onset of the Moon landings, two astronauts would travel to the surface while a third remained onboard the command module to orbit the Moon along, though all of them got chance to orbit the Moon and see the far side before landing. The solo orbital journeys of Michael Collins (Apollo 11), Dick Gordon (Apollo 12), Stuart Roosa (Apollo 14), Al Worden (Apollo 15), Ken Mattingly (Apollo 16) and Ron Evans (Apollo 17), who were the unsung heroes of the Apollo missions, are some of the bravest feats ever achieved by astronauts. They would spend days making quite detailed lunar observations from orbit, mapping features nobody had ever seen before.

Al Worden is often quoted as saying that his time alone was some of the best he had during the Apollo 15 mission.

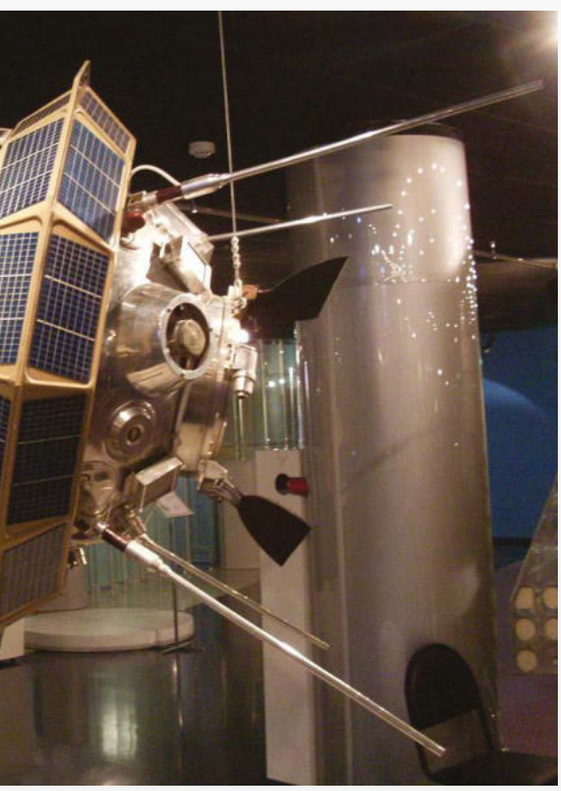
"It was nice to be rid of those guys, as you can

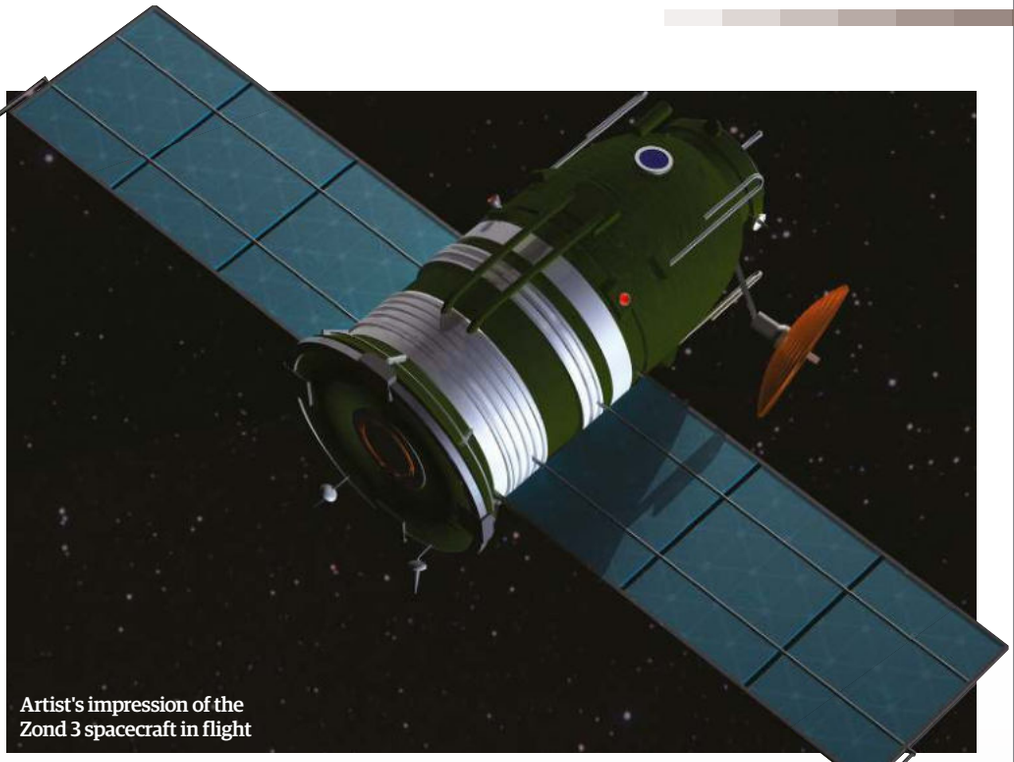
Image showing a replica of the Russian Luna 3 Spacecraft at the museum of aeronautics

In an emergency
A short transit time of 3 days, which astronauts could improve on, allows emergency supplies to quickly reach a Moon colony from Earth or allow a crew to quickly leave the Moon and head back to our planet.

Lunar machines
With a round trip communication delay to Earth being less than three seconds, it allows near-normal voice and video conversation and allows some kind of remote control of machines from our planet.

Moon farms
A lunar farm would be stationed at the Lunar North Pole, allowing for eight hours of sunlight per day during the local summer by rotating crops in and out of the sunlight. Beneficial temperature, protection from radiation and insects needs for pollination would need to be artificially provided.





Artist's impression of the Zond 3 spacecraft in flight

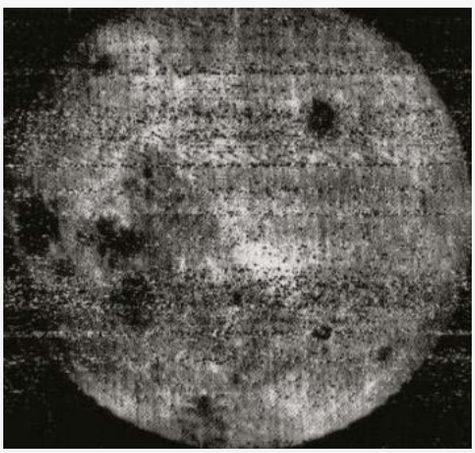
"The far side, the views at certain times, when the Sun and Earth are blocked out, are like nothing you could imagine"

Charlie Duke

imagine, being stuck in something the size of a family car for over a week, it got pretty crowded up there. Once Dave [Scott] and Jim [Irwin] left, I felt like I had some real space to start to do my important work of mapping the lunar surface. But the far side, the views at certain times, when the Sun and the Earth are blocked out, are like nothing you could imagine. The sheer number of stars you see is incredible, it's like a sheet of white, and you know that every single one of them is a Sun in its own right"

A question often asked of the Apollo astronauts and flight teams is, why were all the missions just to the near side?

"We wanted to be in contact with the Earth, so we weren't able to land on the far side of the Moon," says Charlie Duke. Should something have gone wrong while the astronauts were on the surface, they would not have been able to communicate directly with Earth. This would not be such a problem today, as satellites could be put into lunar orbit to relay communications.

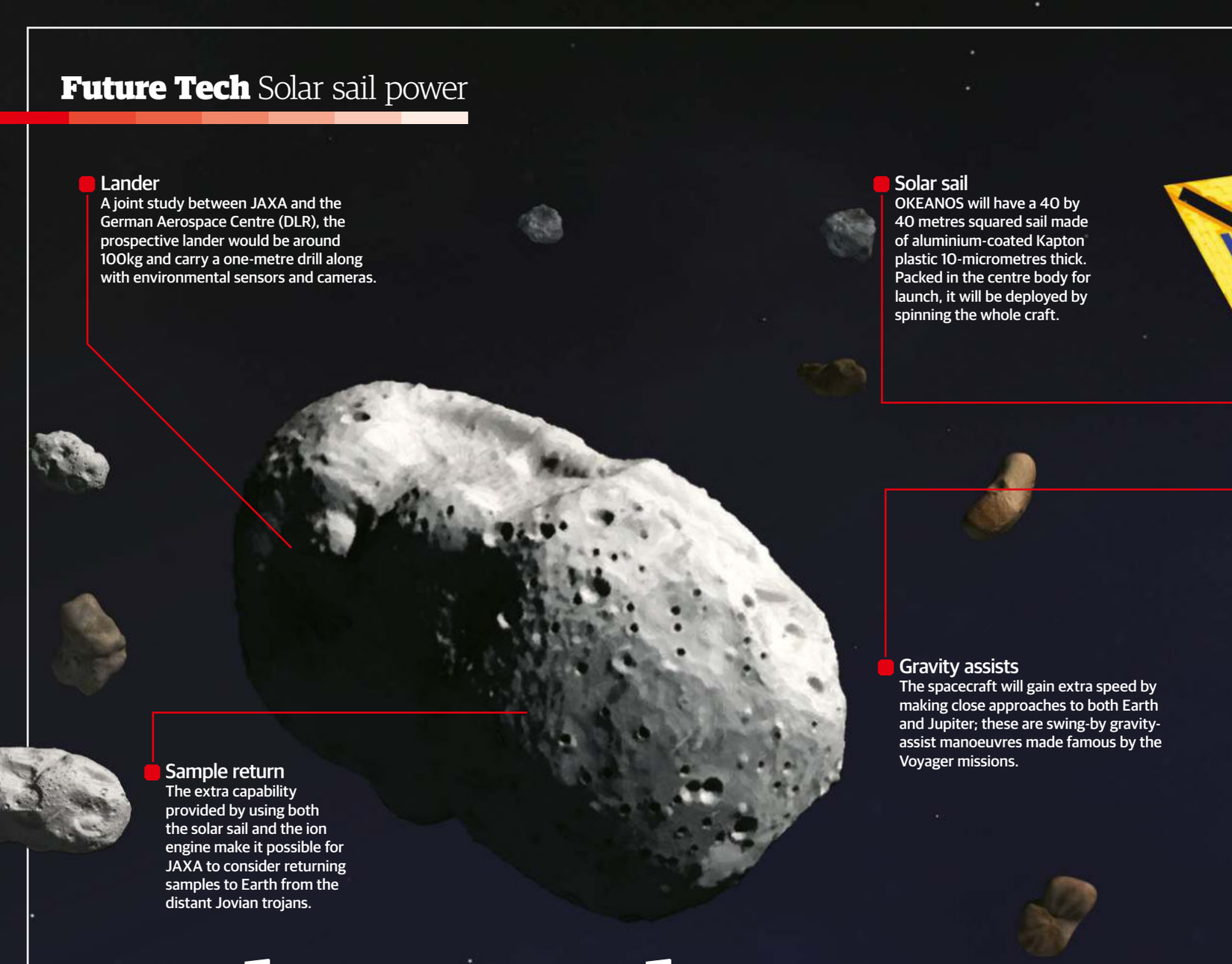


The first image of the lunar far side returned by the Luna 3 spacecraft

The far side is of growing interest to scientists, and potentially future planned human missions. Indeed, the possibilities for the far side of the Moon though are vast. For many decades the astronomical and scientific community have wanted to put radio telescopes and optical telescopes on the far side. Observatories on the far side would be shielded from not only man-made radio interference from Earth, but also the glare of daylight on our planet. The telescopes could be built inside craters to avoid solar radiation, and would provide us with an unprecedentedly clear insight deep into the far reaches of the universe.

We also have little true understanding of the processes that make the far side so vastly different in appearance to the near side. Why it is so scarred with impact craters and so lacking in volcanic mare is even more puzzling when you consider that when the Moon formed, it was much closer to Earth, and may not have necessarily been tidally locked at that time, meaning there would have been nothing special about the hemisphere we dub the far side.

Today, NASA's Lunar Reconnaissance Orbiter has mapped the near side and far side of the Moon in exquisite detail. When humans do eventually return to the Moon, the far side must be a goal for a landing. Understanding it, will give us more insight into not only the Moon's past, but also perhaps the Moon's relationship with Earth our own past.



Solar sail power

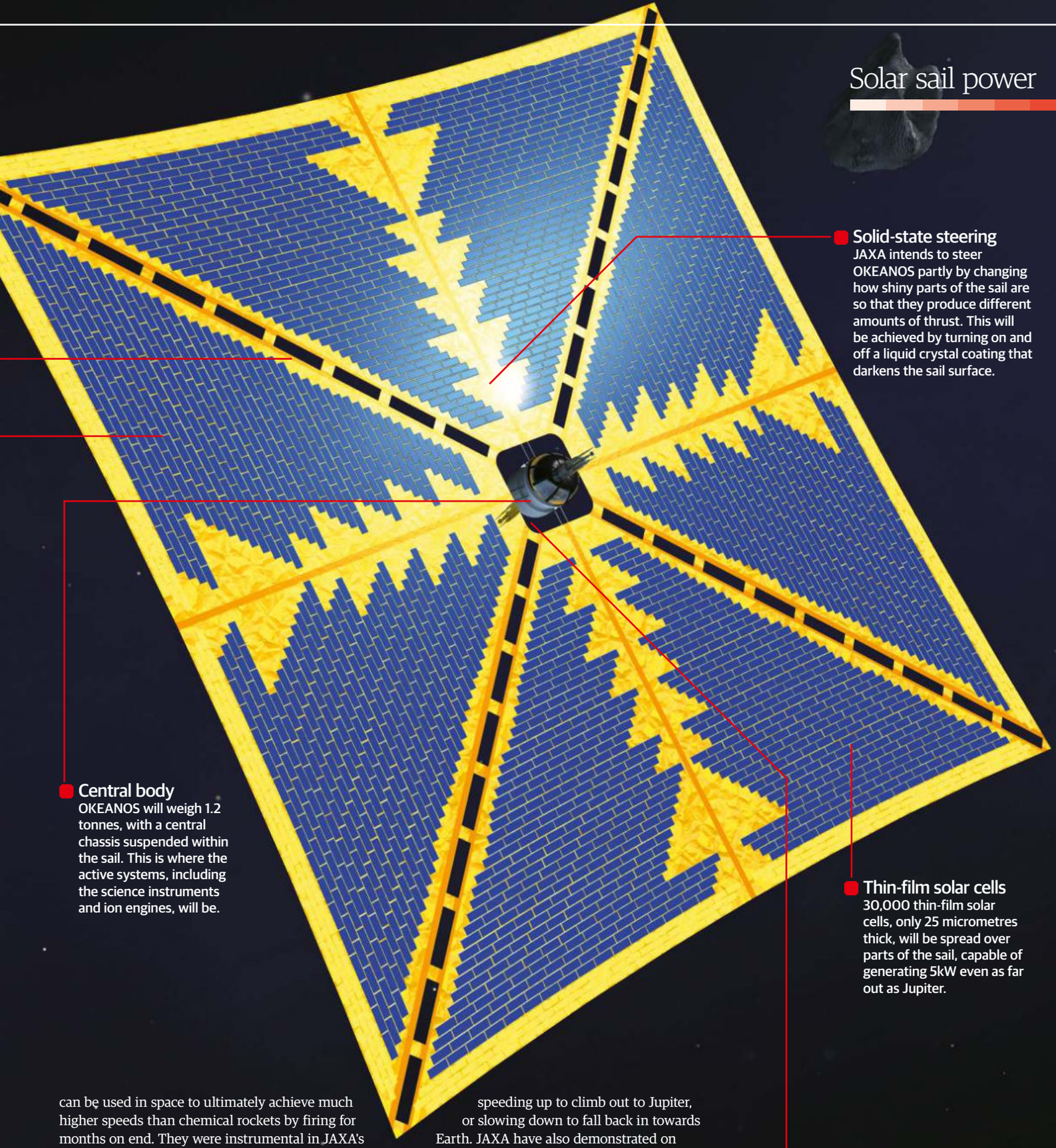
Building upon the success of the IKAROS Venusian solar sail, Japanese Space Agency (JAXA) researchers are proposing an audacious asteroid mission

Recent years have seen spacecraft exploring the smaller bodies of the Solar System. Rosetta and Philae visited a comet nucleus, NEAR Shoemaker surveyed the asteroid Eros before landing on it (despite not being designed to do so) and the Japanese space agency (JAXA) even managed to return a tiny sample of asteroid Itokawa to Earth with their Hayabusa mission. However, these bodies have all been from the inner Solar System, and fascinating primordial matter is scattered throughout, so JAXA are now studying plans to visit Jupiter's trojan asteroids.

Trojans are minor celestial bodies that orbit the Sun in the same orbit as a planet, but not the planet itself. They collect at two places of gravitational stability either 60 degrees ahead, or behind a planet around its orbit. Jupiter's trojan groups are the largest, were first to be spotted and gave their name to this class of object. It is estimated that there are approximately as many Jovian trojans as there are asteroids in the main asteroid belt; smaller groups have been spotted orbiting with Venus, Mars, Neptune, Uranus and even one recently with Earth.

To reach these distant objects JAXA plan to build upon their IKAROS Venusian solar sail, with an ingenious hybrid system called a solar power sail. IKAROS was launched in 2010, and though relatively small for most proposed solar sails at 14 metres squared, it was the first craft to at last demonstrate solar sailing. This is where a large lightweight spacecraft can be propelled simply by the pressure of sunlight bouncing off it; IKAROS also incorporated thin film solar cells for power generation into the sail material.

IKAROS's successor could be OKEANOS. This will be a 40-metres-squared sail also incorporating solar cells, which should generate up to 5KW of electrical power even as far from the Sun as Jupiter. But rather than just powering the electronics OKEANOS' will be used to power an ion engine. This is an electric rocket engine where a heavy gas like Xenon is accelerated electrically to produce a low thrust over a very long time. Though they can't be used inside a planetary atmosphere, ion engines



Solid-state steering
JAXA intends to steer OKEANOS partly by changing how shiny parts of the sail are so that they produce different amounts of thrust. This will be achieved by turning on and off a liquid crystal coating that darkens the sail surface.

Central body
OKEANOS will weigh 1.2 tonnes, with a central chassis suspended within the sail. This is where the active systems, including the science instruments and ion engines, will be.

Thin-film solar cells
30,000 thin-film solar cells, only 25 micrometres thick, will be spread over parts of the sail, capable of generating 5kW even as far out as Jupiter.

Ion engine
OKEANOS will use 2.5kW of the solar cell power during transit to power an ion engine; this produces thrust by electrically accelerating Xenon gas molecules. It can produce a low thrust for months on end.

can be used in space to ultimately achieve much higher speeds than chemical rockets by firing for months on end. They were instrumental in JAXA's own Hayabusa mission and are currently in space aboard NASA's Dawn spacecraft orbiting the dwarf planet Ceres.

So OKEANOS will derive thrust from both solar sailing, and solar-powered ion engines, helping it reach both high speeds and long endurance, making it feasible for JAXA to consider returning samples to Earth. The solar-sail technology can even be used on the return flights, it is not simply a mirror that must be pushed always outwards by the Sun. By angling the sail to the Sun OKEANOS will be able to create thrust along its orbit, speeding up to climb out to Jupiter, or slowing down to fall back in towards Earth. JAXA have also demonstrated on IKAROS how such craft can be steered by manipulating the reflectivity of the sail. The outer sections of the sail are covered with a thin layer of liquid crystal material, as used in digital displays and active privacy windows. When inactive the liquid crystal is transparent to light and the coated areas are as reflective as the rest of the sail. When electrified they obstruct light, selectively making panels dark, so they don't reflect and don't produce thrust. By activating the liquid crystals on different parts of the sail JAXA can direct the thrust effect and steer the sail with no moving parts.

INTERVIEW BIO

Andy Weir

Andy Weir is a former computer programmer, and now a full-time author of science-fiction novels. He received the John W. Campbell Award for Best New Writer in 2016. His ability to combine real science with entertainment is what has made him the popular author he is today.

His most notable work is the creation of *The Martian*, which has sold over 3 million copies worldwide, and was made into a 2015 box office movie featuring Matt Damon and directed by Ridley Scott. Weir's follow-up book, *Artemis* has already hit the shelves, telling an exhilarating tale of lunar mischief.

Andy Weir: the interview

All About Space chats to the author about the inspirations, experiences and underappreciated science that make his science fiction books best sellers - as well as details on his next novel

Interviewed by Lee Cavendish

Where did your inspiration for science fiction and space exploration come from?
I think I was indoctrinated at an early age. Basically my dad is definitely a dork, like myself, and that is the main reason why I'm so nerdy. He was a linear accelerator physicist, which is a fancy way of saying he makes electrons go really fast and hit things. He loved sci-fi all of his life, and so when I was growing up I had access to his science-fiction collection. It was just this giant bookshelf, about six feet tall [1.8 metres], three feet wide [0.9 metres] and a foot deep [0.3 metres] jam-packed full of all the sci-fi novels. I don't think the man has ever thrown away a book.

So I had access to all these sci-fi books from the 1950s and 1960s. I grew up reading baby boomer-era science fiction. Anyway I think I had no hope. I was definitely going to be a science and sci-fi geek from day one.

Your books *Artemis* and *The Martian* are really popular because they strike a nice balance between real science and entertainment. How do you keep that balance when you're writing?
Well, I love real science, so it's easy for me to put all that stuff in. As you have correctly zeroed in on, the hard part is the balance; if I wanted to put in all the science that I wanted to put in, it would read like a Wikipedia article.

It is a constant challenge for me. I am always working on trying to find a way to first off make sure the reader understands enough so that real science is an element of the plot, but at the same time it doesn't bore them to tears.

Don't give them [the readers] any more information then they need for the plot to advance.

The downside of that is that sometimes it requires a bunch of exposition. So far the only trick I have found for that is that the reader will forgive any amount of exposition if it's funny. So if you make them laugh, they'll read page after page of obscure scientific information, as long as it's making them laugh every few seconds. That's my one trick. You now know my one trick.

Are there any parts in *Artemis* and *The Martian* where you really had to put a lot of scientific thought into the story?
Well, in *The Martian* my biggest challenge scientifically was I wanted the orbital trajectory [of Hermes] to be accurate. I wanted the transit times from Earth to Mars, and Mars back to Earth, and all that stuff, because it's a significant plot element. It determines how long he [Mark Watney] would be stranded there, and what they have to do to go get him. Because Hermes is a constantly accelerating craft that has ion engines, it made the calculations incredibly difficult. I once found myself working at tenth-order interval equations, and I was like: "I can't do this. What would NASA do?" I went online and NASA was like: "Oh. We don't do that either." They do everything with simulations.

I was a computer programmer for 25 years, and when the only tool you have is a hammer, every problem looks like a nail. So I wrote the software to help simulate the orbital trajectories step-by-step and increment the time, recalculate the planets' positions and everything like that.

So I never actually had to do the actual math, but that was a lot of work. I spent weeks on that, and the only evidence of all of that work in the book is towards the beginning it says: "it took us 124 days to get to Mars". But I can tell you that number of 124 came as the result of great effort!

Do you have a scientific advisor?
No. I really enjoy the researching science aspect of it. In fact, I don't want to find the answers, but I want to derive the answers myself. In the process of doing that, I start coming up with clever stuff in my mind. It helps me come up with plot elements.

You've said previously that you think *Artemis* is more scientifically accurate than *The Martian*. In what ways is that true?
Well, *The Martian* has technology projected, for lack of a better term, into the future, a bit. For example, the ion engines that power Hermes. The technology exists, but Hermes is a much more scaled-up version of it.

Also, *The Martian* kind of hand-waved around the radiation issues. If you actually spent roughly 500-odd days on Mars, you would have got an extremely harmful dose of radiation from space. I just kind of went: "Oh the Hab [The Martian base] is radiation shielded."

Then, of course, the sand storm at the beginning of *The Martian* couldn't happen on Mars. It's atmosphere is too thin to make a storm of that

NASA astronaut Drew Feustel, Matt Damon, Ridley Scott, Andy Weir and NASA's director of the Planetary Science Division Jim Green participated in a Q&A for *The Martian* film.

The Martian **made over £420 million ($600 million) at the box office**

A lot effort went into calculating the orbital dynamics of the Hermes spacecraft in *The Martian*

Weir gets the opportunity to hold an actual piece of Mars

magnitude. However, *Artemis* is all real technology that can be done right now.

In *Artemis* there is a MacGuffin technology introduced about halfway into the book which is possible, but no one has created it. Other than that, though, everything else is real science, and not even projected that far into the future. For example, Artemis [the city] is powered by reactors that are based exactly on modern-day nuclear reactors, and in fact I've been told that the reactors Artemis uses are actually a little underpowered compared to what we can do today. I used publically available information on reactors, and stuff like that.

Artemis also deals with the radiation problems. The walls of the city are six centimetres (2.4 inches) of aluminium, a metre (3.3 feet) of crushed lunar rock and then another six centimetres (2.4 inches) of aluminium. So I accounted for all these things I kindnof hand-waved for in *The Martian*.

How did you feel when you saw a novel you had spent years writing up on the big screen as a box office hit?

Well I'll tell you, it felt pretty good! [Laughs] I still look back on it as this foggy experience. It was just 'go, go, go' with all sorts of stuff going on all the time. It was hitting me from multiple directions. I never had time to sit back and go, well periodically, I would go: "well this is really awesome!"

But then it was like 'work, work, work'. Looking back on it, it still seems like wait, did that really happen? Because that seems like a ridiculous pipe dream.

> "[Readers will] read page after page of obscure scientific information, as long as it's making them laugh every few seconds"

It seems like the sort of thing you fantasise about in the middle of the day when you should be working. But it actually happened.

Are you happy with how closely the film matched up with the book?

Yes, absolutely. They did a fantastic job of it. Matt [Damon] completely nailed the role. He exactly got the aspect and personality that I imagined Mark Whatney to have. And Ridley Scott was just the perfect choice. If you watch his movies, [you'll notice] he loves slow, landscape shots. He loves giving you a sense of scale of the epic reality that the characters are in. So having him show you Mars really sits well.

I could not have asked for a better production, and it followed the book beat for beat, and in many cases line for line. They did a very, very true-to-the-novel adaptation. They had to take some stuff out; otherwise the movie would be five hours long. But the stuff they took out, if it were up to me, which is very much was not... I would have taken out the same stuff.

Given the recent SpaceX Falcon Heavy launch and NASA's recent announcements to return to the Moon, how do you think the future of space exploration will play out?

Well, I think any advances in space technology are good. NASA has a problem that all government space agencies have, and that is the whims of current leadership pulling it in different directions.

So during the Obama administration it was all about... actually, going even further back, during the [George] W. Bush administration, it was all about "let's go back to the Moon". Then Obama took to office and was like: "No. Cancel that. Instead, we're going to work on asteroid recovery and long-term planning for a mission to Mars." So NASA thought, "OK, we'll work on that." Then Trump's in office and he's like, "Actually, I think we should go back to the Moon."

So NASA have to deal with the issue of the government changing their primarily directives. It's very difficult for them to make progress toward any one goal when every four to eight years, their primary goal gets shifted.

The commercial space industry, however, get to do whatever they want, and that's what I think

is really the path forward. The commercial space industry is just interested in finding a way to make a profit off of space, and that is an entirely different thing, and not at all subject to the changes in government.

What I would love to see actually, more than anything else, is NASA, ESA and other space agencies to get out of the business of making boosters. I would like them all to be concentrating not on the method by which you get into space, but instead concentrating on what you do once they're in space. I would like NASA to concentrate on space stations, interplanetary spacecrafts, probes and whatever else and leave the boosters, leave the actual delivery into orbit, to the private industry.

In the same way, the analogy I'd like to use is let's say I own the Hostess [Brands] company, which makes 'Twinkies'. If I have a factory somewhere in the middle of America where I manufacturer Twinkies, I don't also manufacturer trucks to deliver the Twinkies to grocery stores. I hire a company that has trucks. So that's why I think space agencies should get out of the business of putting things into low-Earth orbit. Let the private industry do that, and that helps create a demand, which helps create competition in the private industry, which helps drive the price down. And then, with the same funding, those agencies could do a lot more.

So you went to NASA's Johnson Space Center...
It was so awesome! It's a nerd dream. I was there for a week. Just every day was multiple VIP tours and they showed me all sorts of awesome stuff, it was great.

Although for me, the highlight of it was they brought me into the Mission Control Centre for the International Space Station [ISS]. Not just the visitor centre, but they let me come out on to the actual Mission Control Centre floor itself. They also let me remote control some cameras that were mounted to the outside of this ISS and they put the feed on the big screen. That was so awesome.

Did you speak to any of the astronauts while you were there?
I did talk to lots of astronauts on the ground, because there are a few of them wandering around there [Johnson Space Center] still in training. But I didn't talk to the ones on the ISS, because they're a bit busy.

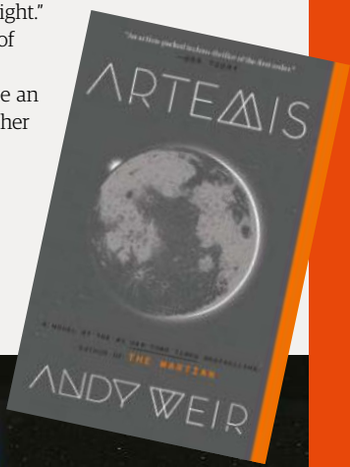
Should we be expecting *Artemis* to be made into a film anytime soon?
Fingers crossed! Twentieth Century Fox has bought the film rights and they have got the director duo of Phil Lord and Chris Miller to direct it. They have a very talented writer named Geneva Robertson-Dworet, she's working on the screenplay adaptation right now. But as the novelist, you are thoroughly out of the loop when they're making a movie. So I'm just an excited bystander, but they're working on the screenplay.

In movie production, with every step you never really know if that's the last step that they're going to bother to work on before throwing the project away. So I just hope that they like it enough, that the studio believes in it and that they make it.

Do you have a personal favourite between the two books?
Everyone is supposed to say I love all my children equally, but I've got to go with *The Martian* because it changed my life. It's what allowed me to become a full-time author. It was just an anomalous story, and when I say 'story', I meant the story behind the story. The events of my life surrounding *The Martian* were just incredible. In 20 years time from now – if I'm still alive, fingers crossed – I'd probably look back on that era, 2014 to 2015, as the best years of my life.

Are you currently working on another sci-fi novel with a different destination in the Solar System?
I have a few ideas for my next book. I even wrote up a chapter and an outline of an idea, and the publisher was like, "Errr... this isn't very good." And I was like, "Errr... you're right."

So I'm still thinking of ideas for what my next book will be. It might be an *Artemis* sequel, or another stand-alone story.



The latest paperback cover of *Artemis* will be released on 3 July 2018

Similar to the plot of *Artemis*, the European Space Agency have already discussed the potential of a lunar base

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Gemma Lavender, Editor

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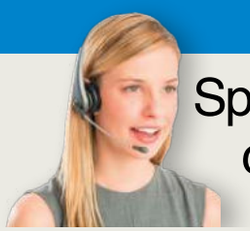

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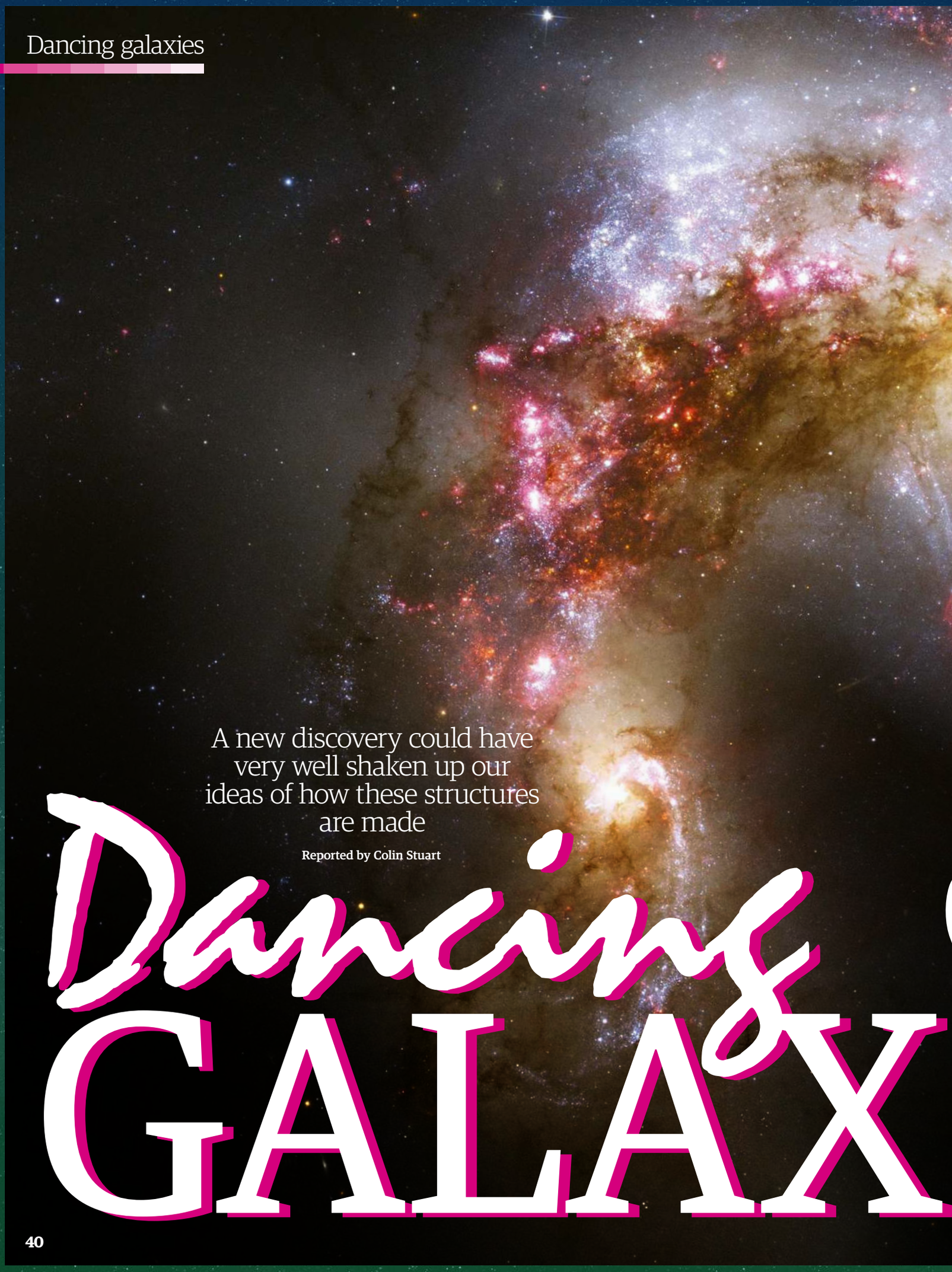


A new discovery could have very well shaken up our ideas of how these structures are made

Reported by Colin Stuart

Dancing GALAXY

Dancing galaxies

Space can be a bit of a mess. Take the moons of Jupiter, for example. Its four largest satellites – Ganymede, Callisto, Io and Europa – all orbit in the same direction around the planet and in the same flat disc. Yet the remaining 65 moons spin around Jupiter at all sorts of random angles and in different directions. That's because the big moons are thought to have formed together with Jupiter. By contrast, the smaller ones were probably passing asteroids or comets caught up in the web of the giant planet's gravity. For the big moons there was some underlying order. The rest have been randomly dumped there over time.

To astronomers studying galaxies, the picture is very similar. These vast collections of hundreds of billions of stars form when smaller objects come together under gravity. Once assembled, they continue to collect material in the form of dwarf galaxies – runts of the litter drawn in by the gravity. By all rights these diminutive orbiters should be trundling around the galaxy at all sorts of random angles depending on the exact trajectory they initially came in from in the first place – just like the smaller moons of Jupiter. "That's what you get when you try and build galaxies in computers," says Oliver Müller, from the University of Basel. These highly detailed computer simulations take into account dark matter. Although it hasn't been detected directly, astronomers think this invisible substance binds cosmic structures together.

Except, the dwarf satellites of the two galaxies we can see best – our own Milky Way and our nearest neighbour, Andromeda – don't appear to play by those rules. They all appear to orbit in a similar plane. It's as if they have been placed there carefully, rather than haphazardly assembled over time. To explain this discrepancy, astronomers have previously dismissed the Milky Way and Andromeda as oddballs that aren't representative of the wider universe, but a new discovery regarding the galaxy Centaurus A is causing a stir. According to a recent study led by Müller, 14 out of 16 of its dwarf galaxies orbit in the same plane. Could it mean our ideas about dark matter are wrong?

Centaurus A is a particularly well-studied galaxy because it has always stood out from the crowd. It was discovered in 1826 by Scottish astronomer James Dunlop while observing the night sky from

Müller hopes future observations with the VLT will help settle the debate

© ESO/M. Kornmesser

Australia. The fifth-brightest galaxy in the sky, it is also one of the nearest active galaxies to us. At its heart is a black hole tipping the scales at 55 million-times the mass of the Sun. The supermassive black hole at the centre of own Milky Way is tiny by comparison at just four million solar masses. Centaurus A's behemoth is gorging on material so vociferously that it creates an intense beam of X-rays and radio waves roaring away from its centre that can be seen through a professional telescope. The galaxy is also undergoing an exceptionally high rate of star formation, probably due to the fact it stemmed from the collision of an elliptical galaxy with a smaller spiral galaxy.

Müller's recent finding regarding its unusually aligned dwarf galaxies is not the first time someone has spotted something odd in the environs around Centaurus A. In 2015, astronomers discovered the region is home to dark globular clusters, dense groups of stars that appear to have much more mass than their constituent stars alone. Perhaps they play host to more dark matter, or maybe they boast a higher population of black holes. Centaurus A was already challenging what we know about galaxy formation and dark matter – Müller's result merely underlines its weirdness.

To study the movement of Centaurus A's dwarf galaxies, Müller used one of the most powerful tools in an astronomer's armoury: redshift and blueshift measurements. We've all heard the effect when a police car screeches by with its siren blasting. When it is moving towards you it is high-pitched, but its pitch drops as it speeds away. That's because it's dragging the sound waves out as it moves further

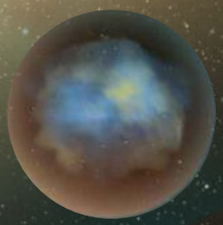
Scottish astronomer James Dunlop discovered Centaurus A in 1826 from Australia

"It's a hard thing to tell when you're observing a galaxy from one angle – as we have to" **Karen Masters**

How we think galaxies are made

Depending on their type - whether they're a spiral or elliptical - these structures follow different evolutionary paths

Spiral galaxies



Lonely cloud of gas

In order for a spiral galaxy to be made, a large and isolated cloud of gas is needed.

The making of stars

Under gravity, the cloud will collapse because there's not enough pressure from the gas itself to fight against this force pressing it down. Baby stars are made in the fight between gravity and pressure.

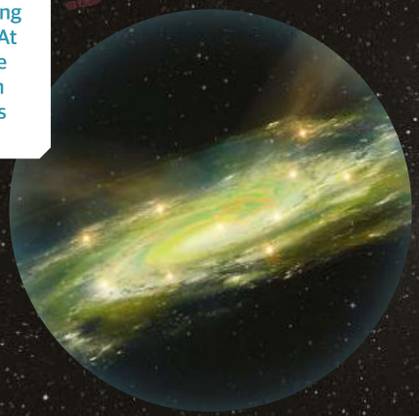
Elliptical galaxies

A team of gas clouds

Small clouds of gas collapse early on to form the galaxy's very first stars.

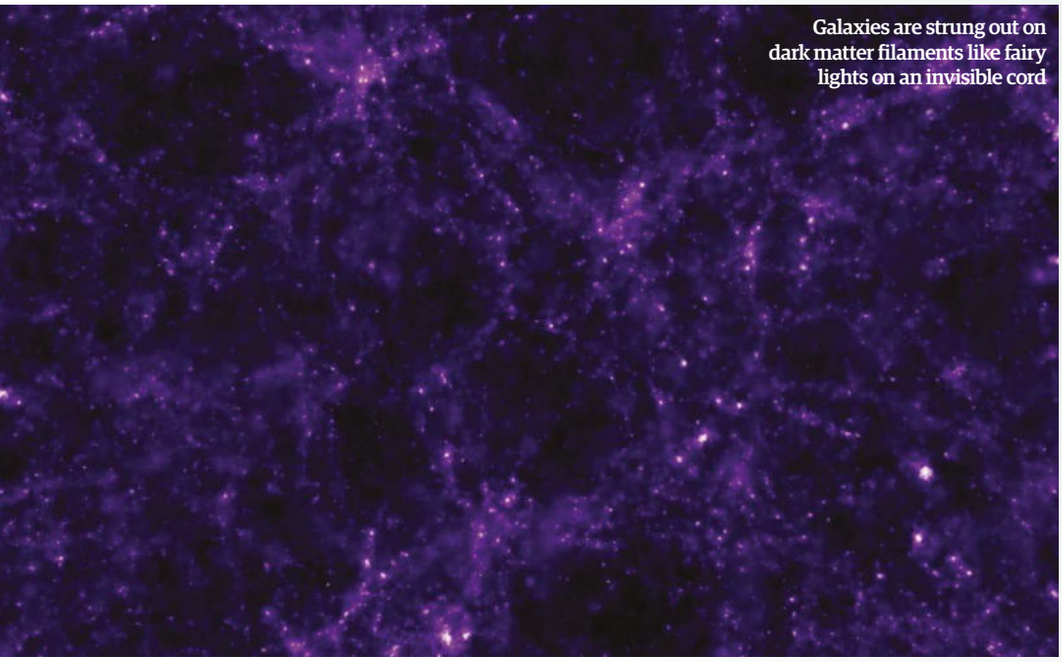
A party of stars

These gas clouds with their newly formed stars clump together to make a larger cloud with a party of stellar proportions.

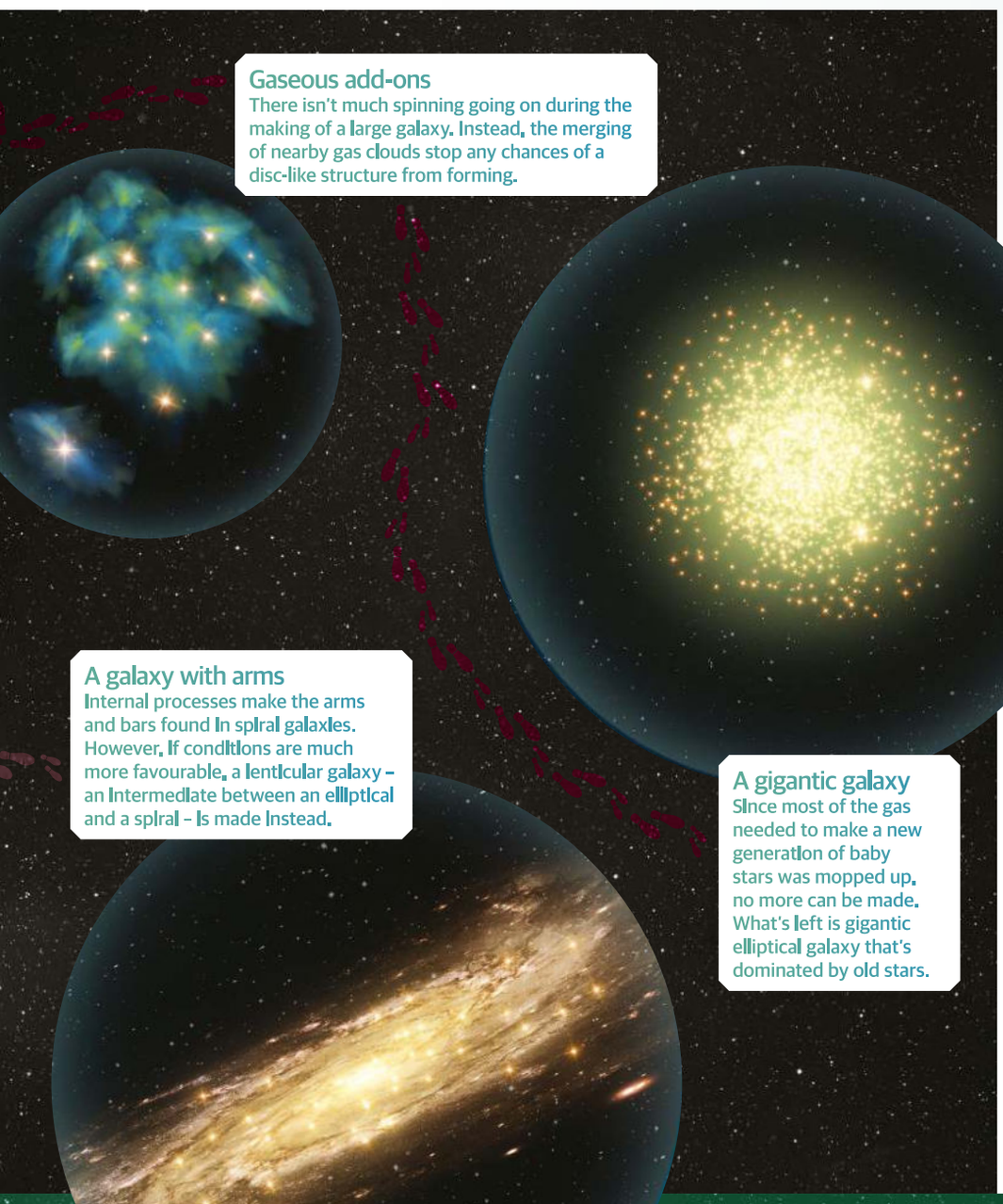


Making a disc

The matter spins quickly, causing a flattened disc-like structure. At the centre is a bulge, where the older, first-generation stars can be found. The rest of the disc is teeming with younger stars.



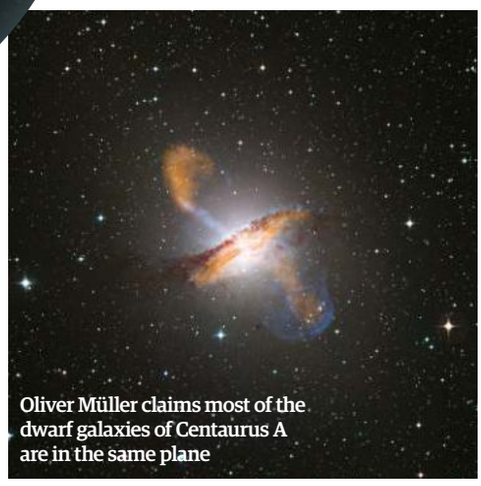
Galaxies are strung out on dark matter filaments like fairy lights on an invisible cord



from you. Light is a wave, too, and moving light sources affect the frequency of its waves. Except it isn't the pitch that changes, but the colour. A light source moving towards you will appear bluer; a receding light seems redder. In practice, the shifts are so small that astronomer's need to look closely at an object's spectrum. Break its light up using a spectrometer – a fancy prism – and you get a spectrum of rainbow colours interwoven with a series of black lines representing missing colours where different chemical elements in the galaxy have swallowed that particular frequency. It is these 'absorption lines' that appear shifted towards the blue or red ends of the spectrum depending on the movement of the dwarf galaxy. The more they are shifted, the faster the dwarfs are moving.

Müller measured the redshift and blueshift of Centaurus A's dwarf galaxies and mapped out their orbital paths to within an accuracy of five per cent, finding almost all of them in the same plane – much like how Jupiter's four largest moons all orbit the planet in a flat disc. How did they end up this way? It's worth saying it could just be a deceptive fluke. Centaurus A has more dwarf galaxies that have yet to be studied. Maybe Müller just happened upon the ones that share an alignment and the rest will turn out not to follow suit. Although he says the chances of that are just 0.5 per cent, if he's right he says it would challenge the status quo that argues such an alignment is hard to achieve in a universe dominated by dark matter. Although some dark matter computer simulations do generate dwarf galaxies in a temporary alignment, Müller says that they are not stable over time and they almost always go back to be being mis-aligned.

Karen Masters, a galaxy expert from Haverford College in Pennsylvania, isn't so sure. "It's a hard thing to tell when you're observing a galaxy from one angle – as we have to – because we live where we live and we don't have a different angle to look from," she says. Masters points to other computer simulations that looked at how often dwarf galaxies may look like they are co-rotating around their host, but in fact that was an illusion caused by our viewing angle. "It's not that unusual to see apparent planes of satellites around galaxies," she says.



Oliver Müller claims most of the dwarf galaxies of Centaurus A are in the same plane

Dancing galaxies

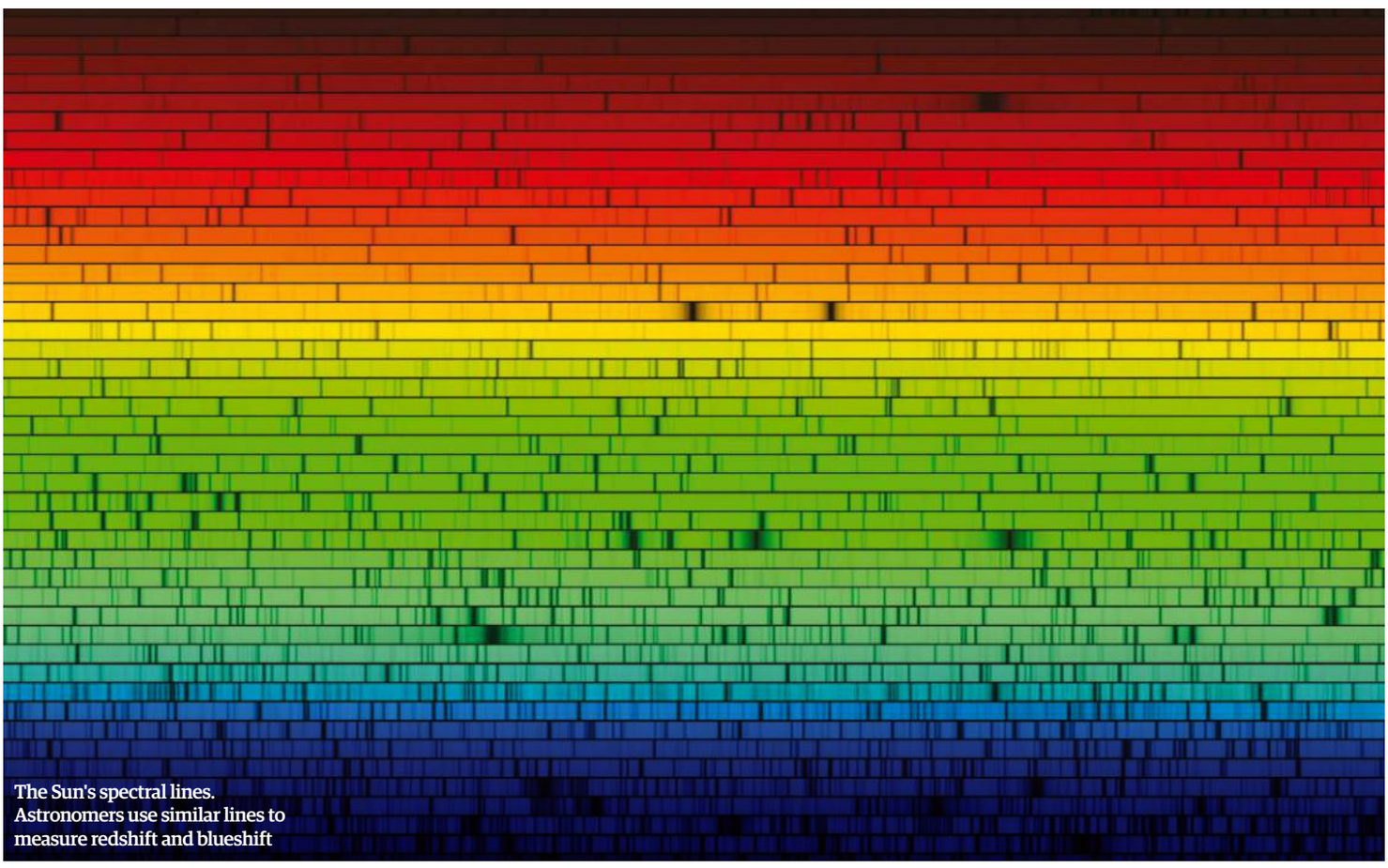
Jupiter's four largest moons share the same plane and direction around the planet

Let's say the alignment is real and the dwarf galaxies really are co-rotating in a plane around Centaurus A. Does that really challenge our ideas about dark matter? Perhaps if you only consider the dark matter and gravity of Centaurus A alone, but there is more to intergalactic space than meets the eye. Galaxies are strung out on vast chains of dark matter known as filaments, like fairy lights dotted along an invisible cord. Back in 2015, a team of astronomers led by Noam Libeskind from the Leibniz Institute for Astrophysics in Potsdam, Germany, mapped out the cosmic web of dark matter in the local universe. They were able to do this by tracing out the trajectories of objects moving through the area under the influence of dark matter's gravitational pull. In doing so they discovered a vast filament of dark matter stretching over fifty million light years from the Virgo Cluster of galaxies across our Local Group. Crucially, four out of the five dwarf galaxy planes they studied were aligned with this filament.

Masters believes that's what's really going on with Centaurus A. "The idea that galaxies should come in from random directions is not a good assumption," she says. "It is based on simulations that were done more than ten years ago." Think of the filaments as rivers of dark matter. Dwarf galaxies get swept up in the current. When you consider this picture of dark matter flowing along filaments between galaxies and galaxy clusters, Masters says dwarfs will end up settling in a preferential direction around galaxies in the direction of the flow. "Why the people who published this don't recognise this I don't know," she says. As far as she's concerned, this result doesn't pose a challenge to our ideas about dark matter – it confirms them when you consider the effect of the shadowy substance on a bigger scale.

Masters isn't the only one not buying Müller's result. Rachael Beaton, from the Carnegie Observatories in California, thinks he has been too optimistic about the accuracy of his measurements. Measuring the redshift and blueshift precisely relies on picking out bright individual stars within the dwarf galaxies. Astronomers have calculated the distance to Centaurus A at between 10 and 16 million light years. From that distance bright stars are in short supply, and Beaton believes that an accuracy of ten per cent is more realistic. If that's the case, there is enough wiggle room for the dwarfs to appear to orbit in the same plane, even though in reality they don't. That would mean there's no challenge to our prevailing ideas about dark matter and its role in galaxy formation. It would, however, shift the emphasis from looking at galaxies as islands in space cut off from each other to seeing them as interconnected in a tangled web of dark matter filaments.

Before astrophysicists throw out Müller's ideas completely, he is planning to examine more of the dwarf galaxies around Centaurus A to firm up the picture. He has already had a proposal accepted to use the Very Large Telescope (VLT) in Chile for such a purpose, and those observations should be made later this year. It is equipped with some of the best spectroscopes in the world, meaning Müller should be able to accurately pin down their blueshifts and redshifts. It remains to be seen if this oddball galaxy will lead to a revolution in our understanding of the universe.



The Sun's spectral lines. Astronomers use similar lines to measure redshift and blueshift

The dance of the galaxies

Synchronised galaxies

Single plane
Centaurus A's satellites have been found to orbit in a single plane, rather than randomly, while it rotates coherently. Dwarfs on one side are receding whilst the others are moving towards us.

Bucking the trend
According to our current theories of the universe, fewer than one per cent of satellite galaxies exhibit similiar behaviour.

Synchronised galaxies
The dwarf galaxies in orbit around Centaurus A have been discovered to orbit their host in a more uniform path.

'Standard' galaxies

Random arrangement
According to what we know to be the 'cosmological ingredients' such as dark matter suggest that small dwarf galaxies should orbit in random positions and directions around their parent galaxy.

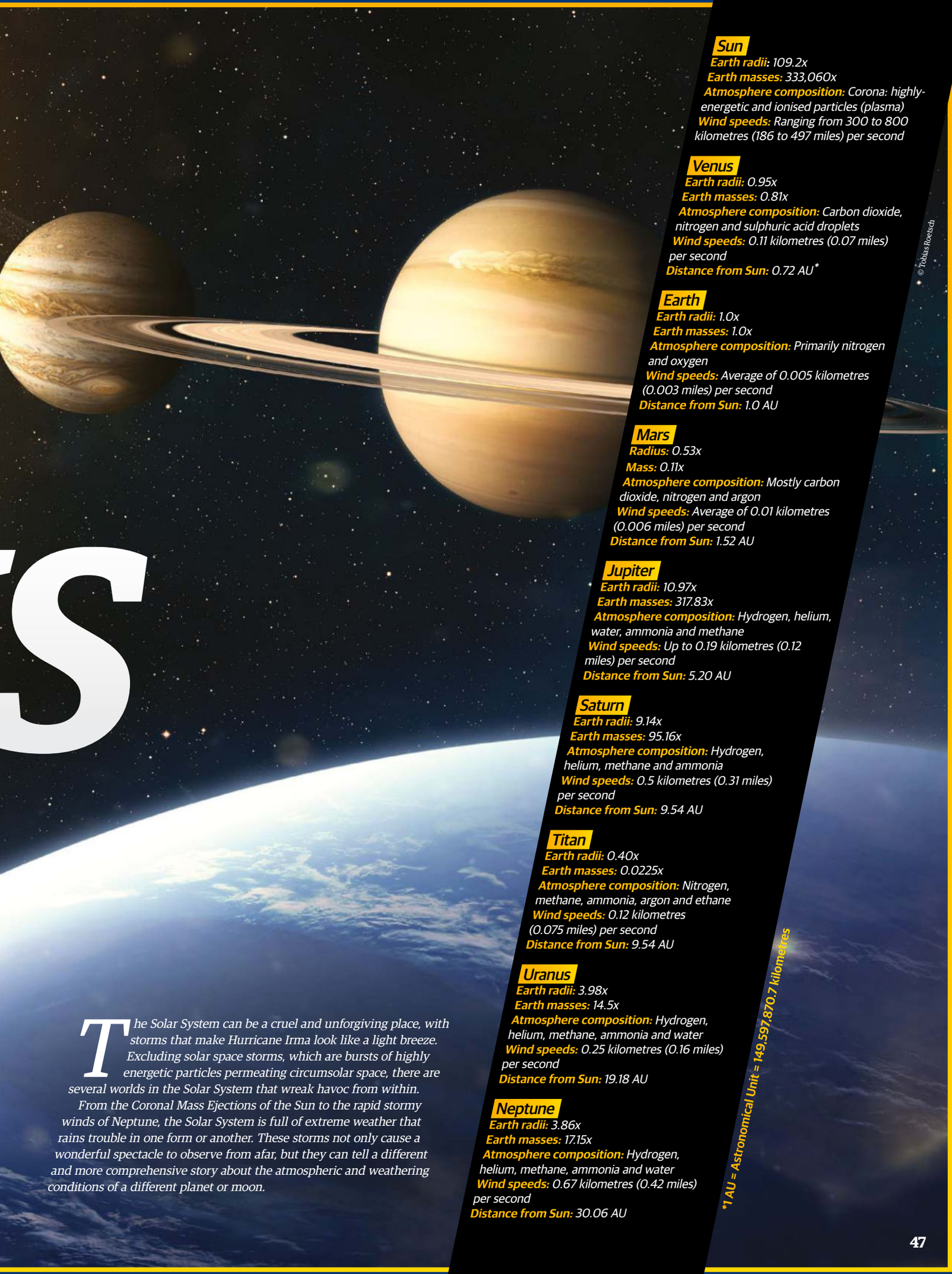
Andromeda & the Milky Way
Our galaxy and neighbouring spiral Andromeda have a mixture of randomly - and coherently - orbiting satellite galaxies.

> "The idea that galaxies should come in from random directions is not a good assumption"
>
> **Karen Masters**

Are our models wrong?
Most of the galaxies that we see today fit in with our models of evolution and cosmology, however, the small per cent of satellite galaxies we observe have left us questioning our theories.

SPACE STORMS

Storms come in all shapes, sizes and degrees of destruction throughout space, but what can they tell us about our Solar System? ***Written by Lee Cavendish***



S

The Solar System can be a cruel and unforgiving place, with storms that make Hurricane Irma look like a light breeze. Excluding solar space storms, which are bursts of highly energetic particles permeating circumsolar space, there are several worlds in the Solar System that wreak havoc from within. From the Coronal Mass Ejections of the Sun to the rapid stormy winds of Neptune, the Solar System is full of extreme weather that rains trouble in one form or another. These storms not only cause a wonderful spectacle to observe from afar, but they can tell a different and more comprehensive story about the atmospheric and weathering conditions of a different planet or moon.

Sun
Earth radii: 109.2x
Earth masses: 333,060x
Atmosphere composition: Corona: highly-energetic and ionised particles (plasma)
Wind speeds: Ranging from 300 to 800 kilometres (186 to 497 miles) per second

Venus
Earth radii: 0.95x
Earth masses: 0.81x
Atmosphere composition: Carbon dioxide, nitrogen and sulphuric acid droplets
Wind speeds: 0.11 kilometres (0.07 miles) per second
Distance from Sun: 0.72 AU*

Earth
Earth radii: 1.0x
Earth masses: 1.0x
Atmosphere composition: Primarily nitrogen and oxygen
Wind speeds: Average of 0.005 kilometres (0.003 miles) per second
Distance from Sun: 1.0 AU

Mars
Radius: 0.53x
Mass: 0.11x
Atmosphere composition: Mostly carbon dioxide, nitrogen and argon
Wind speeds: Average of 0.01 kilometres (0.006 miles) per second
Distance from Sun: 1.52 AU

Jupiter
Earth radii: 10.97x
Earth masses: 317.83x
Atmosphere composition: Hydrogen, helium, water, ammonia and methane
Wind speeds: Up to 0.19 kilometres (0.12 miles) per second
Distance from Sun: 5.20 AU

Saturn
Earth radii: 9.14x
Earth masses: 95.16x
Atmosphere composition: Hydrogen, helium, methane and ammonia
Wind speeds: 0.5 kilometres (0.31 miles) per second
Distance from Sun: 9.54 AU

Titan
Earth radii: 0.40x
Earth masses: 0.0225x
Atmosphere composition: Nitrogen, methane, ammonia, argon and ethane
Wind speeds: 0.12 kilometres (0.075 miles) per second
Distance from Sun: 9.54 AU

Uranus
Earth radii: 3.98x
Earth masses: 14.5x
Atmosphere composition: Hydrogen, helium, methane, ammonia and water
Wind speeds: 0.25 kilometres (0.16 miles) per second
Distance from Sun: 19.18 AU

Neptune
Earth radii: 3.86x
Earth masses: 17.15x
Atmosphere composition: Hydrogen, helium, methane, ammonia and water
Wind speeds: 0.67 kilometres (0.42 miles) per second
Distance from Sun: 30.06 AU

*1 AU = Astronomical Unit = 149,597,870.7 kilometres

Sun

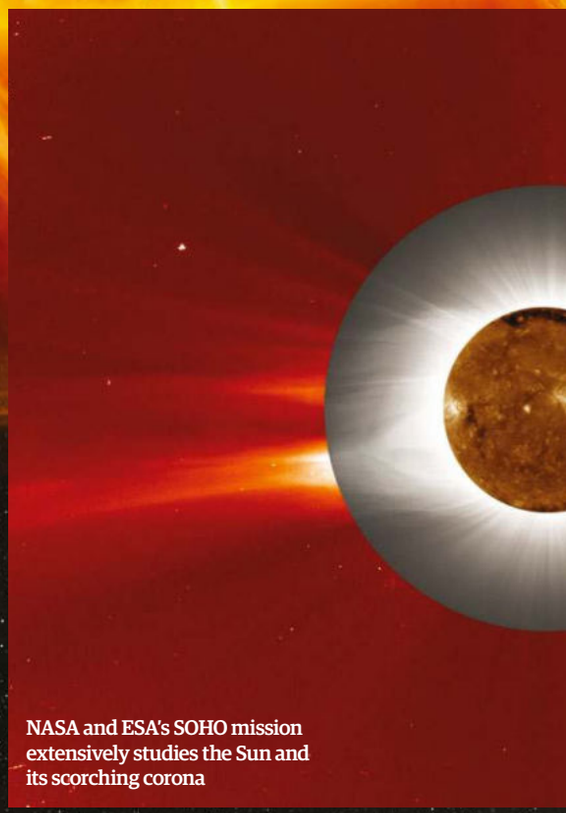
The Sun, the centrepiece of our entire Solar System, doesn't exhibit the same type of storms that we experience here on Earth. Instead, it expels dangerous amounts of energetic particles that cause space storms, which disrupt space weather.

One type of solar explosion – a Coronal Mass Ejection (CME) – jettisons matter from the Sun's corona - the hottest, outermost part of its atmosphere. These expulsions rain down upon everything in the Solar System, affecting any spacecraft or planet in its way as it makes its way towards interstellar space. Yet, these storms shower Earth with the electrons that create the aurora.

What drives these CMEs is a question that astronomers are still trying to answer, particularly Dr Bernhard Fleck, who is the project scientist and mission manager of NASA and ESA's Solar and Heliospheric Observatory (SOHO). "CMEs are the most massive, largest and most energetic explosion events in the Solar System, so they are extremely interesting to study," Fleck tells **All About Space**. "How do they happen? Why do they happen? What drives them? What accelerates them? What heats the plasma? All these questions are fundamental scientific questions."

One of those questions can be answered, and that's what drives them. The answer to this is the Sun's magnetic field. The magnetic field of the Sun cannot be physically observed, but we can measure its strength based on its interaction with surrounding particles. As famous experimental physicist Robert Leighton once said: "If the Sun didn't have a magnetic field, it would be as boring a star as many astronomers believe it is."

But then on 14 October 2014, SOHO watched a spectacular CME escape the clutches of the Sun and accelerate into the cosmos. This CME went on to be detected by ten spacecraft, ranging from ESA's Venus Express all the way to NASA's Voyager 2. "It's very interesting to observe an event like this with so many spacecraft because it gives us a chance to study CMEs not just close to the Sun, or past Earth, but how they develop further out into the heliosphere," says Fleck.

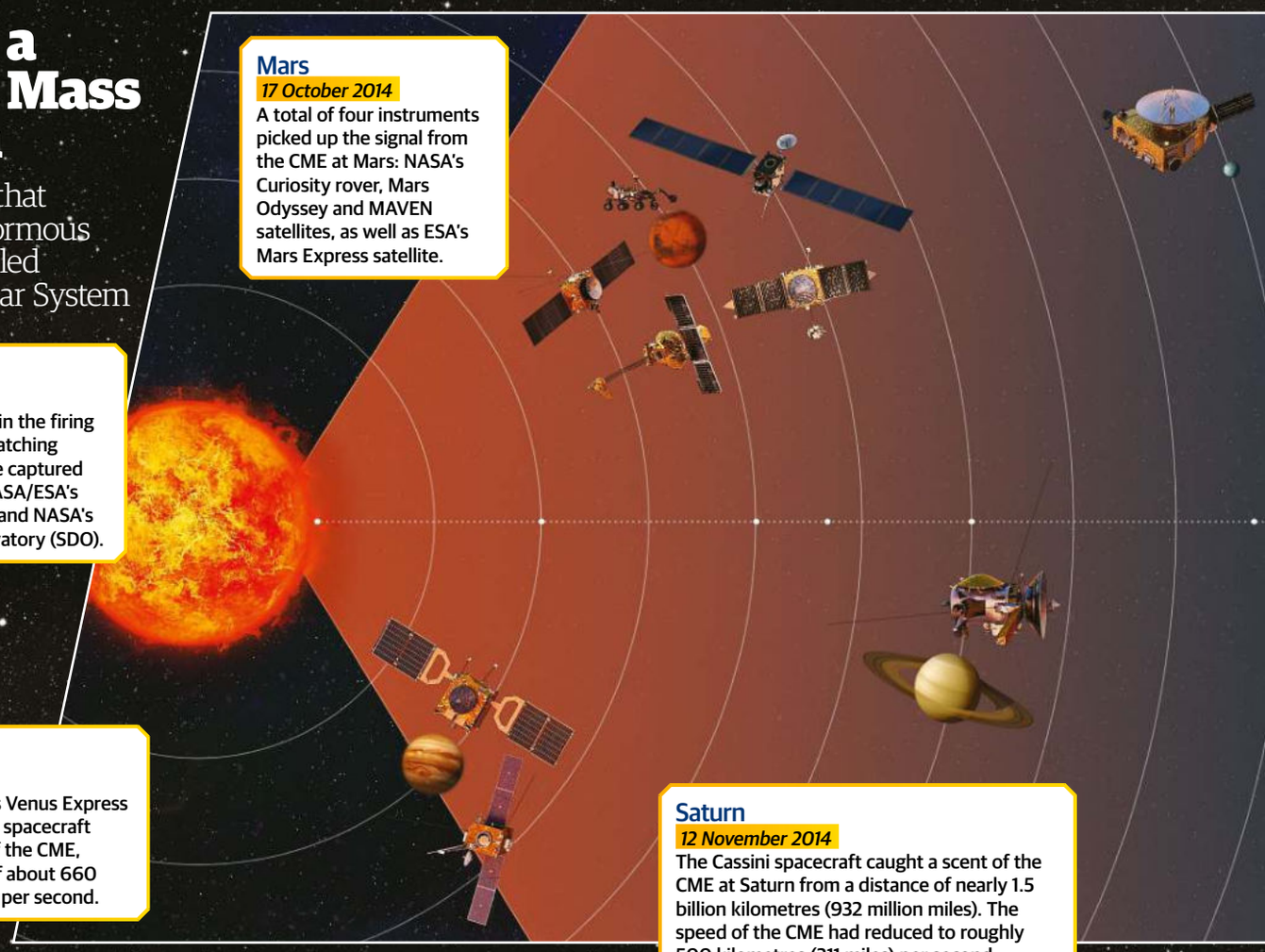


NASA and ESA's SOHO mission extensively studies the Sun and its scorching corona

"CMEs are the most energetic explosion events in the Solar System" **Dr Bernhard Fleck**

Eyes on a Coronal Mass Ejection

The spacecraft that detected an enormous CME as it travelled through the Solar System



Earth
14 October 2014
Although Earth wasn't in the firing line of the CME, Sun-watching satellites close to home captured the event, including NASA/ESA's SOHO, ESA's PROBA-2 and NASA's Solar Dynamics Observatory (SDO).

Mars
17 October 2014
A total of four instruments picked up the signal from the CME at Mars: NASA's Curiosity rover, Mars Odyssey and MAVEN satellites, as well as ESA's Mars Express satellite.

Venus
16 October 2014
A few days after, ESA's Venus Express and NASA's STEREO-A spacecraft picked up the signal of the CME, travelling at a speed of about 660 kilometres (410 miles) per second.

Saturn
12 November 2014
The Cassini spacecraft caught a scent of the CME at Saturn from a distance of nearly 1.5 billion kilometres (932 million miles). The speed of the CME had reduced to roughly 500 kilometres (311 miles) per second.

Hurricane Irma was a Category 5 hurricane that caused catastrophic damage in September 2017

Pluto

January 2015

As NASA's New Horizons' spacecraft made its approach to Pluto, its onboard instruments picked up a disturbance. This was potentially the CME.

Comet 67P/Churyumov–Gerasimenko

22 October 2014

With ESA's Rosetta satellite in orbit around Comet 67P/Churyumov–Gerasimenko, it managed to measure a disturbance that aligns with the CME that just previously visited Mars.

Interstellar space

Late March 2016

Likewise to the New Horizons' signal, NASA's Voyager 2 spacecraft detected a disturbance as it travelled through space. It has yet to be confirmed, but this detection was made over a year and five months after the initial eruption.

Earth The first-hand storm experience

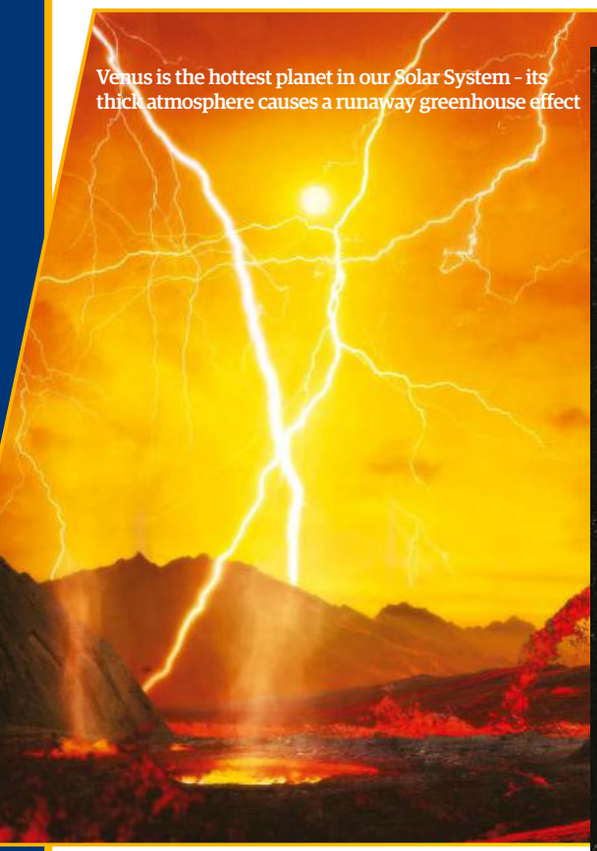
By looking at the eight balls of rock and gas orbiting the Sun, a range of storms have been observed. These storms arise from disruptions within their different atmospheres, but only on Earth do we get first-hand experience of these events. Most are extremely unpleasant to experience, but what is learnt from them not only tells us a lot about our own planet, but this knowledge can also be applied to the atmospheres of the rest of our planetary family.

Storms can come in different forms, including tropical cyclones, thunderstorms, hailstorms and sandstorms. From studying the storms that arise on Earth we have been able to determine a number of factors responsible, including atmospheric and water cycles, temperatures, wind speeds and humidity.

The key ingredient for a tropical cyclone on Earth is warm ocean water. Throw in a sprinkle of high-speed winds and this can bring about a hurricane, typhoon or tornado. As the warm ocean water evaporates and condenses into clouds higher in the Earth's atmosphere, condensation releases more heat to create an unstable network of clouds. With the wind whisking up these clouds in this dangerous region, a tropical cyclone is born.

In a different, but fairly similar scenario thunderstorms can occur over someone's head. The same indifference between warm air evaporating and cold air higher up condensing causes hailstones in the process. These hailstones move within clouds and cause a negative charge that is collected at the base of the cloud. When the attraction between the negative clouds and Earth's positive surface becomes too much, magnificent flashes of thunder and lighting roar overhead.

In either case, scientists have been able to deduce how these arise, and it tells us a lot about the weather cycles and atmosphere on Earth. By seeing storms on other planets we can apply this same knowledge to tell us more about the troubling worlds we have yet to even visit.



Venus is the hottest planet in our Solar System – its thick atmosphere causes a runaway greenhouse effect

Venus

Earth's feverish sibling is home to vicious thunder and acidic rain

Venus is the closest thing there is to hell, with its scorching surface temperatures can reach 471 degrees Celsius (880 degrees Fahrenheit), sulphuric acid rain, active volcanism and thunderstorms. The European Space Agency's (ESA) first spacecraft to Venus – the Venus Express – was in orbit between 2006 and 2014, trying to peer through its thick atmosphere onto the surface lurking below.

In November 2007, the existence of thunderstorms on Venus was confirmed based on data taken by Venus Express' onboard magnetometer. This was fantastic news at the time, as it was the only planet other than Earth, Jupiter and Saturn able to generate lightning. On the original three planets it was known that interactions of water clouds produce thunder and lightning, but there is no such thing on Venus. The only explanation is that there is some form of electrical current build-up in the clouds of sulphuric acid, an exhilarating concept in terms of planetary sciences.

Based on what we know about how thunder and lightning form on Earth, planetary scientists say that instead of clumps of water ice bumping into each other, causing the negative electrical build-up, it is instead sulphuric acid-ice. A strange idea to think about, however, there is not enough evidence to disprove that theory at the moment. Only if another mission goes back to explore the boiling ball of rock that is Venus will astronomers and planetary scientists gather the data necessary to confirm or deny such an idea.

Mars

Although its atmosphere is thin, Mars can still summon an almighty dust storm

In order to whip up a good storm, you need a fairly sized atmosphere. Unfortunately for Mars, this is not the case. Its atmosphere is virtually non-existent when you compare it to the likes of its terrestrial siblings Earth and Venus. This means Mars doesn't experience the same kind of hurricanes, thunderstorms or even rain that we are familiar with. Despite that, another type of storm has been known to make an appearance on Mars, and that's a dust storm. Mars' atmosphere may be incredibly thin, but it produces enough wind to shake up the dust surface of Mars into a global dust storm.

While the dust storm spreads across the face of Mars, it can also cause atmospheric gas escape from the planet, contributing to the disappearance of an already-thin atmosphere. Dr Nicholas Heavens, research assistant professor of planetary science at Hampton University, Virginia, United States, tells **All About Space**, "Dust storms bring water vapour from near the surface to high altitudes where it dissociates into hydrogen and enriches the upper atmosphere in hydrogen that escapes Mars's atmosphere."

Heavens made it clear that these results can also tell us a lot about the past life of Mars, to a point where it had a more stable atmosphere and liquid water on the surface. "At some point, Mars probably was a warmer, wetter planet with a thicker atmosphere. Scientists are always looking for an explanation for where the water went," says Heavens. "The connection between dust storms and hydrogen escape can only be a partial explanation, because the mechanism requires a drier planet with a thin atmosphere to work well."

Hazy vision
A dust storm can cause a global haze, making it difficult to deduce previously visible features.

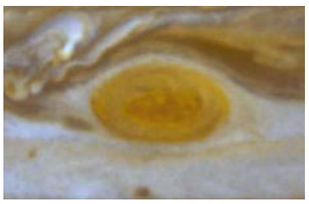
Seeing the Martian surface
During a dust storm, features such as the Meridiani Planum are clearly visible.

Dust storms may be linked to Mars' disappearing water

Changes to the poles
The difference in size of the icy south pole is a clear indication of how much the dust storm can haze the surface.

Check-up by Cassini
A passer-by in the form of NASA, ESA and ASI's Cassini-Huygens spacecraft captured the most amazing images of Jupiter and its GRS on its way to Saturn in December 2000.

Galileo's gander
NASA's Galileo spacecraft became the first craft to orbit an outer planet, taking this roughly true-colour image on 26 June 1996.



Here at Hubble
In 1996, the newly stabilised Hubble Space Telescope turned its optics to Jupiter in order to study the ever-changing nature of the GRS.

Juno's giant view
On 10 July 2017, NASA's Juno spacecraft flew over the GRS, and imaged it at about 13,917 kilometres (8,648 miles) above the clouds of Jupiter.

Voyager 1's view
Voyager 1 was the first spacecraft to visit Jupiter in February 1979. As it passed, Voyager snapped an image of the GRS and its surroundings.

Jupiter

The Jovian atmosphere creates spectacularly enormous storms that are visible from Earth

Jupiter is a gaseous world that is renowned for its massive storms, the most famous of which is the Great Red Spot (GRS). After hundreds of years of observations, scientists are still uncovering secrets about this mysterious feature with NASA's Juno space probe.

"One of the most basic questions about Jupiter's Great Red Spot is: how deep are the roots?" says Scott Bolton, Juno's principal investigator from the Southwest Research Institute in San Antonio. "Juno data indicates that the Solar System's most famous storm is almost one-and-a-half Earths wide, and has roots that penetrate about 200 miles [322 kilometres] into the planet's atmosphere."

However, the iconic spot appears to be shrinking. About 150 years ago it was a size that could incorporate three Earths with room to spare. Whereas astronomers expected the Jovian winds to increase in speed as they contract (conservation of angular momentum), instead the storm actually stretches up, much like clay being shaped on a potter's wheel.

From Earth, we can only see Jupiter from an edge-on perspective. It wasn't until the Juno spacecraft got closer that astronomers could see the poles. What they saw was not what they were expecting. Not only do both poles consist of an enormous single central cyclone with several circumpolar cyclones, but they also appear to coexist in peace.

"These [polar] cyclones are huge, with winds speeds as great as 220 miles [354 kilometres] per hour," says Bolton. "These novel features seem to exist in harmony, close together and persistent. They are surprisingly different from the single storm pattern that the Cassini spacecraft measured at Saturn's poles."

There is still much to learn about Jupiter based on these complex and thought-provoking storms, but with Juno still orbiting Jupiter and gathering as much data as possible, there is much to learn about the dynamics of Jupiter. For instance, knowing that the wind speeds of the GRS haven't sped up with shrinkage, we can determine that the roots of the storms reach deeper than first thought. This helps astronomers determine the depth of the Jovian atmosphere.

"The Solar System's most famous storm is almost one-and-a-half Earths wide" **Scott Bolton**

Saturn

The ringed planet gives rise to a gigantic storm roughly every 30 years

Much like the Juno spacecraft at Jupiter, Saturn had its own visitor, NASA's Cassini spacecraft. For 13 years, Cassini watched over the ringed gas giant that is Saturn, and in that time the spacecraft returned unrivalled data and awe-inspiring images.

In December 2010, a dramatic storm arose on the face of Saturn, one of many that have occurred over the past decades, which astronomers have dubbed the 'Great White Spots'. The distinctive streaks of anarchy stretched across Saturn's surface and continued to grow. Cassini was able to watch the storm over this period, as lightning storms raged within and the winds reached speeds of up to 576 kilometres (358 miles) per hour.

"With Cassini and ground-based data we were able to track the main vortex that was the source of the storm, as well as study the general circulation of the storm itself and to measure lightning coming from the storm," Dr Linda Spilker, project scientist of the Cassini mission explains to **All About Space**.

When asked about what these storms could tell us about Saturn's atmosphere, Spilker replied: "These events occur once every 30 years or so – once every Saturn orbit about the Sun – and release a tremendous amount of energy into the atmosphere."

As for how these storms arise, again it is not well understood. However, a mechanism has recently been suggested, which matches observations. This mechanism details how the cooling of the planet's upper atmosphere overpowers and suppresses the internal convection. Due to Saturn's extremely cold atmosphere, it takes roughly 30 years for the air to warm up and rise to create the thunderstorms.

Doesn't this sound familiar to thunderstorms on Earth? Although the atmospheres of the two planets are completely different - Earth having an atmosphere of primarily heavy molecules and Saturn having mostly hydrogen and helium - the occurrence of such an event revolves around similar mechanisms.

Cassini observed a lightning signal from deep in the planet's atmosphere in 2010

Titan

Saturn's largest moon has a thick atmosphere with rainstorms drenching the surface in hydrocarbons

Saturn's minor companion, Titan, is an interesting target for astronomers, as its surface it abundant in liquid methane and ethane, the building blocks for complex compounds like DNA. It is also the only known moon with a dense atmosphere, making it visually appear covered in an orange fog.

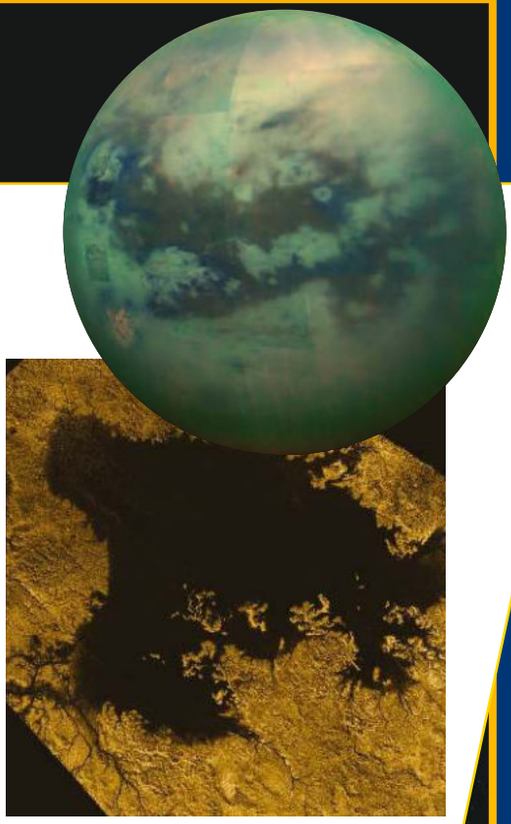
With the presence of a dense atmosphere and large quantities of liquid methane, a theory confirmed by NASA/ESA/ASI's Cassini-Huygens mission and a host of contributing scientists state that troublesome weather is bound to terrorise the surface of this distant moon.

"Cassini saw evidence for a giant methane rainstorm on Titan that wet part of the surface," Spilker explains. "We then watched that surface dry out over the next several months. We saw clouds and evidence of other storms as well."

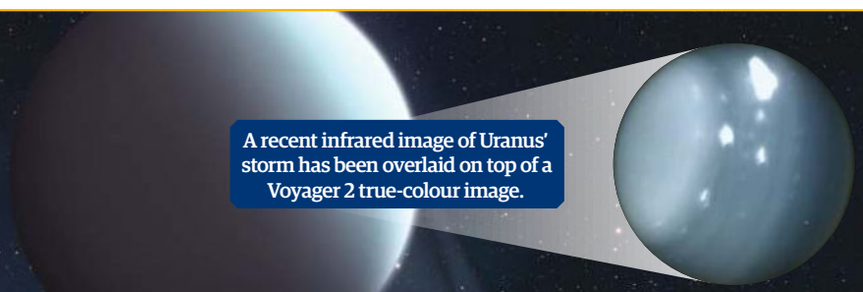
"Storms on Titan are part of Titan's seasonal weather cycle and help us understand the weather on Titan. They also tell us about surface erosional processes," Spilker continues.

Erosional processes that sculpted out riverbeds, channels and dunes are relatable to those observed on Earth. For instance, Lake Poopó in Bolivia was once a majestic saline lake – the second-largest – but its now dried up, and what's left is a geological dent in the surface of Earth. These same types of 'dents' have been seen on the surface Titan, and this tells astronomers and planetary scientists a lot about weather processes on Titan.

There is a lot of talk about going back to Titan with NASA's proposed Dragonfly drone, and this would be able to fully investigate its environment. The organic chemistry, habitability, atmospheric and surface conditions could be studied in unprecedented detail, and this would provide valuable data is explaining how these storms occur on Saturn's largest moon.



Ligeia Mare is the second-largest known body of liquid on Titan



A recent infrared image of Uranus' storm has been overlaid on top of a Voyager 2 true-colour image.

The ice giants

Uranus and Neptune have storms that travel mysteriously quickly across their faces

The icy duo may seem dull from afar, but that is far from the case. Their blue surfaces may seem like inconspicuous balls of hydrogen, helium and traces of volatiles, but they exhibit some of the most extreme and violent storms in our Solar System.

In comparison to Uranus', and in particular Neptune's winds, Earth's winds are barely even noticeable. Uranus exhibits wind speeds of up to 900 kilometres (560 miles) per hour, but it's Neptune that holds the title of the 'Solar System's windiest world' with supersonic speeds of up to 2,414 kilometres (1,500 miles) per hour.

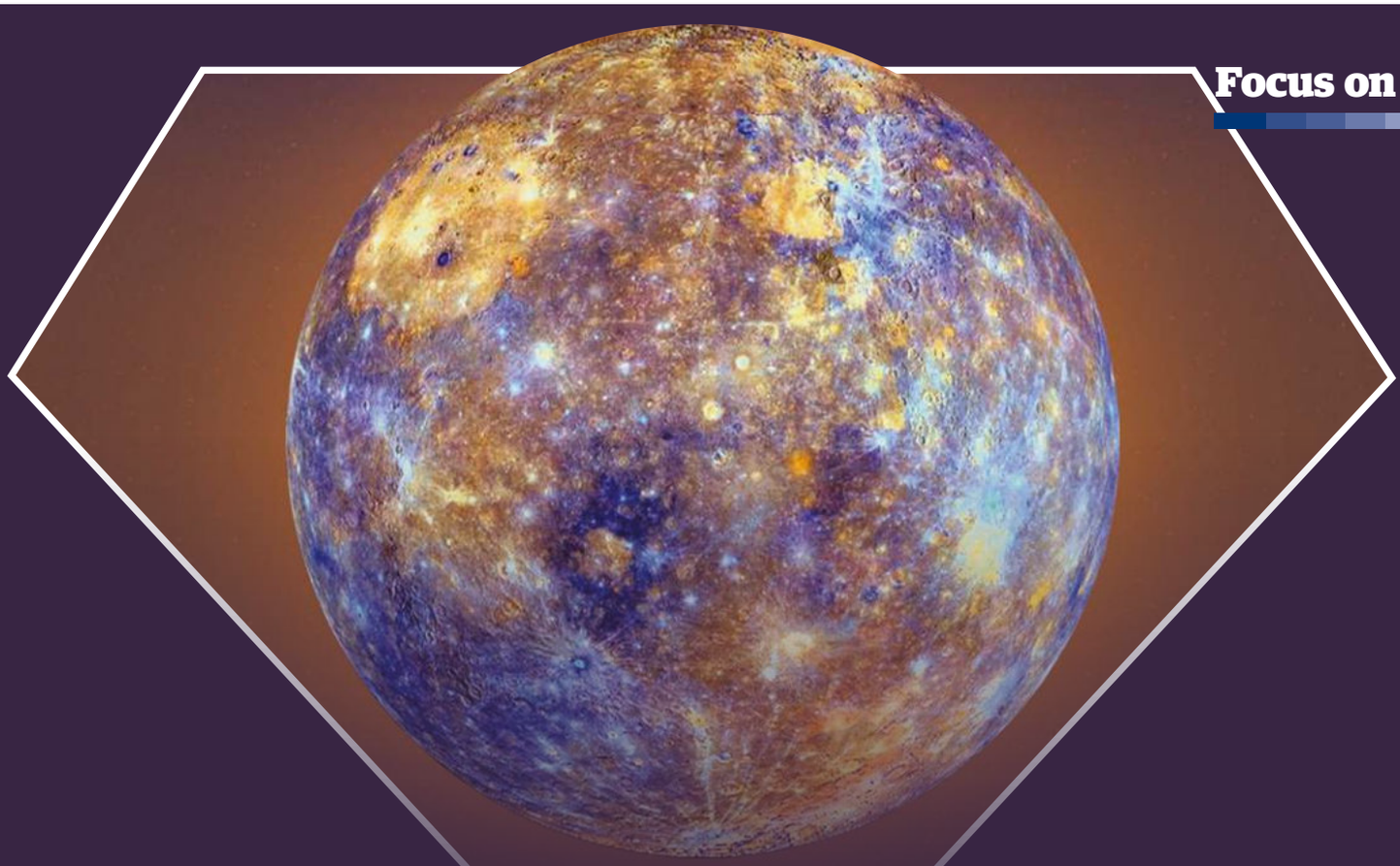
Back in 2012, astronomers used the telescopes at the Keck Observatory in Hawaii to observe the ice giant, Uranus, in near-infrared wavelengths. This revealed complex weather containing circulating clouds, massive hurricanes and an unusual swarm of convective features at its north pole.

As for Neptune, the most powerful storm that has been observed was the Great Dark Spot, which stirred much public interest during the Voyager 2 flyby in 1989. Since then, astronomers have primarily relied on the Hubble Space Telescope and other ground-based telescopes to watch out for discrepancies. Only last year, the Keck Observatory saw a troublemaker arise on Neptune in the form of a massive storm system stretching roughly 9,000 kilometres (5,592 miles) in length.

"This big vortex is sitting in a region where the air, overall, is subsiding rather than rising," says Professor Imke de Pater of UC Berkley's Astronomy Department. "Moreover, a long-lasting vortex right at the equator would be hard to explain physically."

Since weather is driven by the heat of the Sun, and sunlight is 400-times weaker at Uranus, and over 900-times weaker at Neptune, than at Earth, the solar energy driving these systems are a mystery. By studying storms such as these, astronomers are continuously gaining a clearer picture of what is powering these powerful winds from within, as the absence of solar energy is not enough. What is clear is that both atmospheres must operate very efficiently with very little energy squandered in order to maintain the drastic atmospheric variations required to summon these storms.

The only spacecraft to visit the ice giants, Voyager 2, managed to image Neptune's Great Dark Spot in 1989.



DIAMONDS FROM A LONG-LOST PLANET

Scientists studying the meteorite up close have found evidence that it could have come from a Mercury-sized world that no longer exists

A meteorite that recently struck Earth has found to contain diamonds that were infused in a planetary embryo some billions of years ago. After carefully analysing the microscopic diamonds hidden within asteroid 2008 TC3 - which entered the Earth's atmosphere on 7 October 2008 - the best explanation for its creation is that it was made within a protoplanet with an equivalent size ranging from Mercury to Mars.

The asteroid met its demise as it shattered into tiny fragments 37 kilometres (23 miles) over the Nubian Desert in Sudan. Only 50 of these fragments were ever found, ranging in size from one to ten centimetres and collectively weighing in at 4.5 kilograms (9.9 pounds). These pieces now go by the name of Almahata Sitta, which is Arabic for 'Station Six', the nearby train station.

These meteorites are mostly ureilites which are incredibly rare, as they contain segments of tiny diamonds. There are three possible scenarios in which the diamonds could have formed. First of all, they could have formed from 'normal' static pressure inside a body, which is how most diamonds on Earth are formed. Secondly, there is the deposition by chemical vapour, and lastly it could be due to enormous pressure shockwaves caused by a collision of a huge parent body and a cosmic collider. Researchers at the École Polytechnique Fédérale de Lausanne (EPFL) in Switzerland used a combination of advanced transmission electron microscopy techniques to deduce that the most likely scenario is the third.

The constituents of the shimmering space diamonds include chromite, phosphate and iron-nickel sulphides. These have been found in many Earth-based diamonds, but this is the first time they have been detailed in an extraterrestrial object. The composition and morphology tells a vague story, but the story implies that the diamonds were formed within a Mercury- to Mars-sized planetary parent body under pressures of at least 20 gigapascals (GPa).

These results not only give us a sample of what exotic materials can be found travelling through the dark ocean of nothingness that is space, but also provide more evidence for the theory that multiple protoplanets crowded our Solar System in its early years. Many of the protoplanets are thought to be Mars-sized, for instance, the protoplanet that struck the Earth and resulted in our lunar companion, more commonly known as the Moon.

The sample of meteorite diamonds

25 great space days out

From space hardware and rocket launches to planetariums and observatories, Earth is full of out-of-this-world attractions

Just like the universe itself, the world is full of hidden astronomical wonders that deserve exploration. So how about a day out where you can learn more about space, space exploration and astronomy?

For stargazers and anyone wanting to know more about the night sky, there are some wonderful planetariums. Most hold seasonal shows, though the projections are now so technologically advanced that you should also expect full-dome 3D films. There are space centres that double as observatories in the evening, offering educational exhibitions by day and real-life stargazing by night – and perhaps even a chance to peer through a big telescope.

Elsewhere there are fabulous museums stuffed with space hardware, from natural wonders such as Moon rock and meteorites from other planets, to landmark space artefacts with incredible stories to tell. A Saturn V rocket, the Apollo 11 capsule and even Neil Armstrong's spacesuit can be viewed if you know where to look. More modern spaceships are also on display; the Space Shuttle Atlantis can now be visited in Florida. London's Science Museum has just put Tim Peake's Soyuz capsule on show. If you have the money you can beat all that; get yourself to Kazakstan and you can see astronauts and cosmonauts blast-off for the International Space Station on the top of a Soyuz rocket.

1 Jodrell Bank Discovery Centre

Stand under the iconic Lovell Telescope at the UK's centre of radio astronomy

Where in the world: Macclesfield, Cheshire, UK
Website: jodrellbank.net
Telephone number: 01477 571 766
Cost of admission: Adults £8, Child/Concession £5.95, Family (2+2) £26.50, Family (2+3) £31

Home to the world-famous Lovell Telescope, a visit to Jodrell Bank makes for an exhilarating day out. Seeing the near 90-metre-high radio telescope up close and in action is an incredible experience, and the Discovery Centre's exhibitions, interactive displays and galleries will help you understand how it works and what it's looking for.

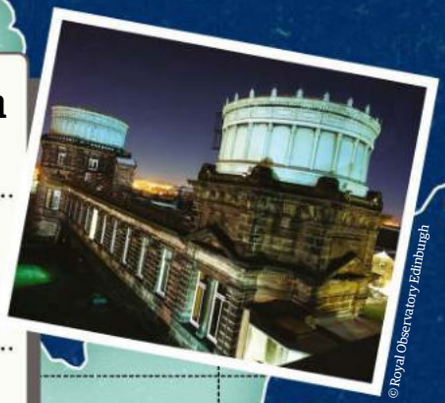
You'll also find 35 acres of gardens and arboretum complete with picnic areas, playground, galaxy garden and the pop-up Potting Shed Café. There's plenty of extra activity throughout the year too, including the ever-popular family science shows, an evening lecture series and of course, the annual science and music festival Bluedot.

2 Royal Observatory, Edinburgh

The HQ of Scottish astronomy in a Victorian telescope dome

Where in the world: Edinburgh, UK
Website: roe.ac.uk
Telephone number: 0131 668 8404
Cost of admission: Adults £4, child/concessions £3 (for summer astronomy evening)

Hold a meteorite, explore the observatory's historic Victorian telescope dome and look at planets and the Moon through telescopes (clear skies allowing) at the centre of astronomy in Scotland. Public Astronomy Evenings are staged every Friday night from October until April.



© Royal Observatory Edinburgh

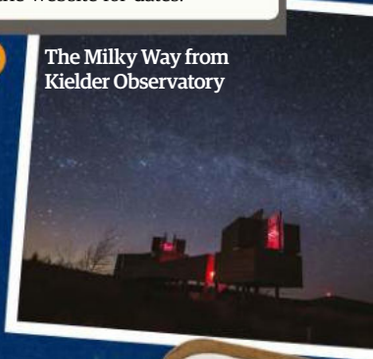
3 Kielder Observatory

A stargazer's paradise near the Scottish border

Where in the world: Northumberland, UK
Website: kielderobservatory.org
Telephone number: 0191 265 5510
Cost of admission: Adult from £18.15, concessions/children from £16.50

Though you can generally roam around during the day, this observatory – its location near the Scottish border chosen because of a lack of light pollution – is generally only open for specific events. The most popular is February's Aurora Nights, though Night Sky Safaris and astrophotography sessions are also staged. Check the website for dates.

© Kielder Observatory



1 The Milky Way from Kielder Observatory

4 Techniquest

Hands-on science exhibits and a full-dome planetarium

Where in the world: Cardiff, Wales, UK
Website: techniquest.org
Telephone number: 029 2047 5475
Cost of admission: Adults £8, children/concessions £6.50, under 3 years free, family (up to 5, max. 2 adults) £28

This science and technology discovery centre in the Welsh capital's buzzing Cardiff Bay has over 160 hands-on, interactive exhibits. It's also got a planetarium which uses a full-dome projector to explore the night sky during shows aimed at audiences of all ages, even toddlers.

We The Curious' 3D planetarium

© James Beck

5 We The Curious

Gaze up in the UK's only 3D planetarium

Where in the world: Bristol, UK
Website: wethecurious.org
Telephone number: 0117 915 1000
Cost of admission: Adults £15.95, Children £10.50, Family (up to 4, max. 2 adults) £45.00. Planetarium show additional 3D £3.50, 2D £2.50 Planetarium Nights £7.50/£8.50 adult, £6.50/£7.50 concession

This science centre has the UK's only 3D planetarium, and while it has shows for kids during the day, it also hosts the adults-only Planetarium Nights on most Thursday evenings. The latter's two shows include timeless classics Exploring the Solar System and Exploring the Galaxy.

6 The National Space Centre

Visit the UK's largest attraction dedicated to space exploration and space science

Where in the world: Leicester, UK
Website: spacecentre.co.uk
Telephone number: 0116 261 0261
Cost of admission: Adult £14.00, child (5-16) £11.00, concessions £11.00, under 5s free

Discover six interactive galleries, the UK's largest planetarium, unique 3D Simulator experience and the iconic 42-metre-high Rocket Tower. The ticket also includes entry to the on-site Sir Patrick Moore Planetarium.

The National Space Centre includes a 360-degree full-dome cinema

© The National Space Centre

7 Royal Observatory Greenwich

East meets west at the home of GMT & Universal Time

Where in the world: Greenwich, London, UK
Website: rmg.co.uk/royal-observatory
Telephone number: 020 8858 4422
Cost of admission: Adult £10.00, child £6.50, concession £8.10, children under 4 free

Standing on the Prime Meridian where east meets west at longitude 0 degrees is Greenwich Mean Time (GMT), but more importantly for astronomers it's also Universal Time (UT) that everything in the night sky is measured to. Overlooking the River Thames, you can also see an 18-tonne Victorian telescope and sample London's only planetarium.

8 Science Museum

See Tim Peake's Soyuz spacecraft & Apollo 10's Command Module

Where in the world: London, UK
Website: sciencemuseum.org.uk
Telephone number: 0333 241 4000
Cost of admission: Free (donation suggested)

An absolute must-visit for anyone interested in space exploration, London's Science Museum has seven floors of exhibits, including the Apollo 10 command module and the Soyuz TMA-19M spacecraft used by Tim Peake in 2016. Its theatre also shows Legend of Apollo, a 3D computer animation based on the Apollo lunar landings.

Tim Peake's Soyuz spacecraft at the Science Museum

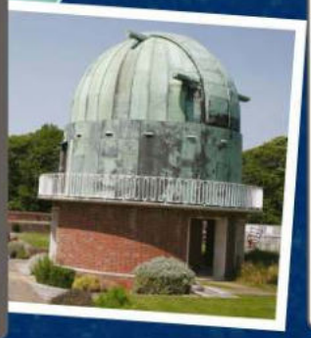
© Jody Kingzett, Science Museum

9 The Observatory Science Centre, Herstmonceux

Six green domes of historic telescopes are the centrepiece of this hands-on experience

Where in the world: Hailsham, East Sussex, UK
Website: the-observatory.org
Telephone number: 01323 832 731
Cost of admission: Adults £9.10, children £6.90, family (2+2) £28.30, family (2+3) £32.25

Home to the giant 98-inch Isaac Newton Telescope (INT) since 1967, expect daily telescope tours, interactive hands-on exhibits and spectacular science shows. The centre stages an annual astronomy festival in September and hosts courses such as Introduction to Astro-Imaging and a 12-week Astronomy and Space For Beginners course.



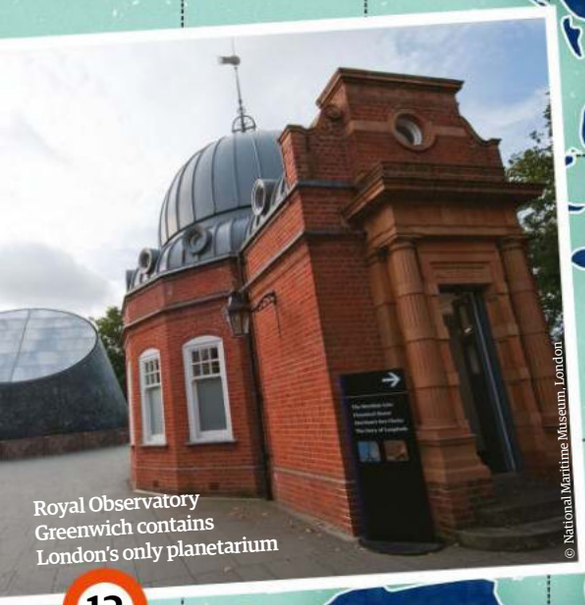
©Mark Mercer / Alamy Stock Photo

10 South Downs Planetarium & Science Centre

See a show dedicated to local hero Tim Peake

Where in the world: Chichester, West Sussex, UK
Website: southdowns.org.uk
Telephone number: 01243 774 400
Cost of admission: Public shows, adults £7.00, children (under 16) £5.00

The UK's biggest planetarium on the grounds of Chichester High School Campus runs excellent stargazing shows such as Summertime Stars, Moon and Planets and Summer Nights, Shooting Stars, as well as one show dedicated to UK astronaut Tim Peake, who is from the Chichester area. Nearby at The Novium (**thenovium.org**) you can see the Tim Peake: An Extraordinary Journey exhibition.



Royal Observatory Greenwich contains London's only planetarium

© National Maritime Museum, London

11 Charleville Cosmos Centre

There is no better place for stargazing than the Australian Outback

Where in the world: Charleville, Queensland, Australia
Website: cosmoscentre.com
Telephone number: 07 4654 7771
Cost of admission: Adults $10, concessions $10, child $8, family (2+2) $28

Deep in the Australian outback (though only a short flight from Brisbane), by day you can handle meteorites and sip a 'Light Year Latte' or a 'Saturn-shire Tea' in the Cosmos Cafe. By night the roof slides off a nearby observatory for guided stargazing using a fleet of huge Meade telescopes.

Far from light pollution, the Cosmos Centre is fun day or night

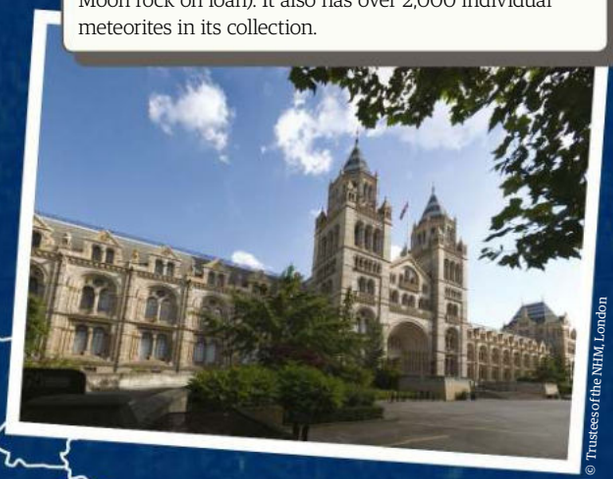
© Charleville Cosmos Centre

12 Natural History Museum

Moon rock and meteorites at this world-class museum

Where in the world: London, UK
Website: nhm.ac.uk
Telephone number: 020 7942 5500
Cost of admission: Free

Although it's the Science Museum just around the corner that has the most space artefacts, this great museum holds the only piece of Apollo Moon rock owned by the UK (though the National Museum of Wales in Cardiff has Moon rock on loan). It also has over 2,000 individual meteorites in its collection.



© Trustees of the NHM, London

13 Baikonur Cosmodrome tour

Watch a Soyuz spacecraft lift-off to the International Space Station

Soyuz Launch Pad at Baikonur

© NASA/Bill Ingalls

Where in the world: Baikonur, Kazakhstan
Website: starcity-tours.com/baikonur
Telephone number: +7 (495) 506 32 23
Cost of admission: From 2,700€ per person

What could be better than watching cosmonauts and astronauts climb into a Soyuz spacecraft and blast-off into space? A five-day tour from Moscow is hugely expensive, but does include flights from Moscow and a room in Hotel Sputnik.

14 Pic du Midi Observatory

Stargaze from atop a telescope-studded mountaintop that helped map the Moon

Where in the world: Pyrenees, France
Website: picdumidi.com
Telephone number: 05 62 56 70 00
Cost of admission: Adult 40.00€, child 24.50€, family (2+2) 98.00€

This astronomical observatory 2,877 metres up on a ridge can be visited by day via cable car from La Mongie ski resort. It's Night At The Summit package includes the cable car, meals, an astronomy talk and an overnight stay (from €339) where you can see the telescope NASA used to map the Moon (among others), and stargaze from its fabulous terrace.

15 El Roque de Los Muchachos Observatory

This multinational mountaintop houses Europe's best telescopes – and you can go inside them

Where in the world: La Palma, Canary Islands
Website: astrolapalma.com
Telephone number: +34 622805618
Cost of admission: €9 per visitor (Sun, Tues, Fri & Sat)

The air may be thin 2,450 metres up on this volcano in the Canary Islands, but it's thick with Europe's best telescopes. Book ahead online and you can visit one of them on a 90-minute tour, usually the William Herschel Telescope, a 4.2-metre (165-inch) optical/near-infrared reflector.

La Palma is where Europe's biggest telescopes live

© Jamie Carter

16 USS Hornet Sea, Air & Space Museum

See the 'splashdown recovery' ship for Apollo 11 and Apollo 12 and lots of other memorabilia

Where in the world: San Francisco, California, US
Website: uss-hornet.org
Telephone number: (510) 521-8448
Cost of admission: Adult $20, senior/military/student $15, Child $10 (close for general admission on Tuesdays)

The aircraft carrier that rescued the crews of both Apollo 11 and Apollo 12 after their splashdown has memorabilia, photos and an Apollo Command Module used in testing by NASA astronauts.

Mobile Quarantine Facility onboard the USS Hornet

©USS Hornet Sea, Air & Space Museum

17 Armstrong Air & Space Museum

In the hometown of Neil Armstrong are artefacts from some of his greatest achievements

Where in the world: Wapakoneta, Ohio, US
Website: armstrongmuseum.org
Telephone number: (419) 738-8811
Cost of admission: Adults $8, seniors $7, child (6-12) $4, 5 and under free

It's designed to look like a Moon base, and it's convincing on the inside, too; here you'll find Neil Armstrong's Gemini 8 and Apollo 11 space suit (he was from Wapakoneta), though his gloves and helmet are on display at Smithsonian's National Air and Space Museum. You can also see Moon rock and the historic Gemini 8 spacecraft flown by Armstrong.

©Jamie Carter

18 Griffith Observatory

Peer through the world's most popular telescope

Where in the world: Los Angeles, California, US
Website: griffithobservatory.org
Telephone number: (213) 473-0800
Cost of admission: Free

Over seven million people have looked through the 12-inch Zeiss refracting telescope on the roof of Griffith Observatory. You can queue up to take a look yourself, then gaze across LA as the lights come on before descending to the front lawn to look through a bevy of large telescopes set up by volunteers each evening.

19 NASA Mission Control, Johnson Space Center

Drop in on the International Space Station's Mission Control

Where in the world: Houston, Texas, US
Website: spacecenter.org
Telephone number: (281) 244-2100
Cost of admission: Adult $29.95, senior $27.95, child $24.95 + $6 for audio tour

Second only to witnessing a rocket launch must be the hallowed Level 9 Tour ($179.95) at the Johnson Space Center, which lets you see the International Space Station (ISS) Mission Control. The tram tour also includes historic Mission Operations Control Room 2 (used in the Apollo era), a Saturn V rocket designed for the cancelled Apollo 19 and a lunar module.


Johnson Space Center's Mission Control Center

©NASA

©Jamie Carter

20 Lowell Observatory

See where Pluto was discovered on Mars Hill in 1930

Where in the world: Flagstaff, Arizona, US
Website: lowell.edu
Telephone number: (928) 774-3358
Cost of admission: Adults $15, seniors/military/students $14, children $8, under 5s free

During the day tour you can see the historic Pluto Telescope and the Clark Telescope, then walk the fabulous scale models of the Solar System and the universe in the surrounding ponderosa pine forest on Mars Hill. At dusk, staff set up huge 16-inch telescopes on the lawn. Below is Flagstaff, a Dark Sky Community with Route 66 running through it.

21 Meteor Crater

A Moon-like hole in the ground where Apollo astronauts trained

Where in the world: Winslow, Arizona, US
Website: meteorcrater.com
Telephone number: (800) 289-5898
Cost of admission: Adults $18.00, children $9.00

This mile-wide impact crater left by a Near-Earth object slamming into the planet 50,000 years ago is the best preserved you can see in the world, and it's a stunning sight. As well as a viewing platform on the rim complete with telescopes, there's a new museum and walking trails. It's on the way to and from Grand Canyon via Flagstaff.


Meteor Crater is 30 miles east of Flagstaff, Arizona

©Flagstaff Convention & Visitors Bureau

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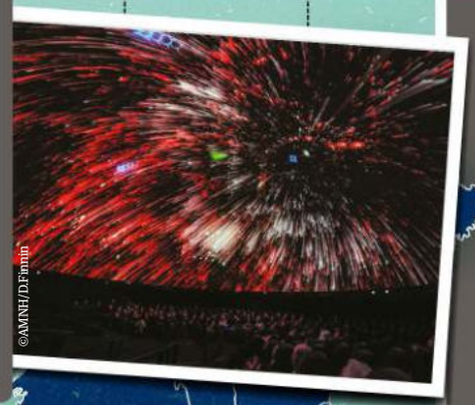
22 Hayden Planetarium

See Neil deGrasse Tyson's Planetarium at the American Museum of Natural History

Where in the world: New York City, US
Website: amnh.org
Telephone number: (212) 769-5100
Cost of admission: Adult $28, senior $22.50, child $16.50 for general admission plus one Hayden Planetarium Space Show

'The world's largest cosmic atlas' is what's promised by the Hayden Planetarium, a cutting-edge installation at the American Museum of Natural History near Central Park in Manhattan. Directed by Neil deGrasse Tyson, the planetarium uses a Zeiss Mark IX star projector to produce film-like shows with awesome production values.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©NASA

23 Kennedy Space Center Visitor Complex

See a Saturn V rocket while you're on holiday in Florida

Where in the world: Florida, US
Website: kennedyspacecenter.com
Telephone number: (855) 433-4210
Cost of admission: Adult $50, child (under 12) $40

The Space Shuttle Atlantis has got to be the primary reason to visit Florida's Kennedy Space Center, but don't underestimate the shock at seeing a Saturn V rocket – the largest ever built and exactly the same as the one that took Apollo 11 to the Moon. Apollo 14's command module is also here.

24 Smithsonian's National Air and Space Museum

See the only hardware that returned from the first Moon landing

Where in the world: Washington DC, US
Website: airandspace.si.edu
Telephone number: (202) 633-2214
Cost of admission: Free

Is this the most precious space artefact in the world? Housed in the Boeing Milestones of Flight Hall is the Apollo 11 Columbia command module that carried Armstrong, Aldrin and Collins to the Moon's orbit and back, while nearby is the artefact-packed Apollo to the Moon exhibition.

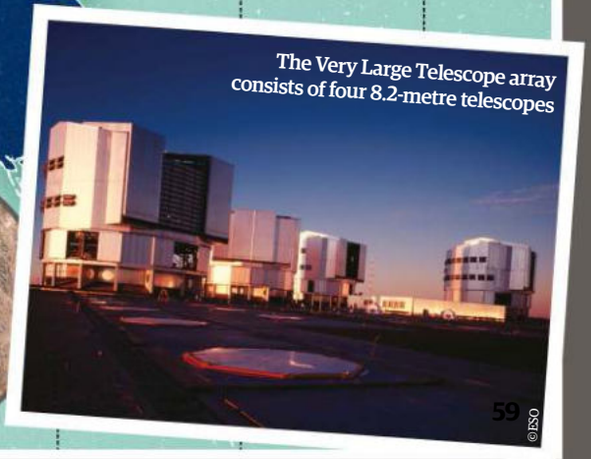
The Apollo Lunar Module in the Boeing Milestones of Flight Hall
©Mark Avino/Smithsonian's National Air and Space Museum

25 Cerro Paranal

See the planet's best telescope at the 'astronomy capital of the world'

Where in the world: Atacama desert, Chile
Website: https://www.eso.org/public/about-eso/visitors/
Telephone number: +56 55 243 5100
Cost of admission: Free guided tour, must register in advance

The highest, driest place in the world is where you can see the planet's most advanced ground-based optical instrument, the European Southern Observatory's Very Large Telescope (VLT) array. Visitors are welcome to join a guided tour on Saturdays, which includes a close-up of the four 8.2-metre 'scopes.


The Very Large Telescope array consists of four 8.2-metre telescopes
©ESO

MISSION PROFILE

New Horizons

The mission that made the first flyby of Pluto continues to break records and gather important data as it explores the vast Kuiper Belt

Mission type
Space probe
Operator
NASA
Launch date
19 January 2006
Target
Pluto and the Kuiper Belt
Arrival at Pluto
14 July 2015
Primary objective
To study the Kuiper Belt region
Status
Active

Dr Alan Stern
Principal investigator for NASA's New Horizons mission
Dr Alan Stern is the principal investigator for NASA's New Horizons mission, and has been since the very beginning. Stern is currently the associate at the Southwest Research Institute in Boulder, Colorado, United States, and has a long list of credentials, including his work as a planetary scientist, space program executive, aerospace consultant and also an author.

Exploring the outer regions of our Solar System is a perilous and burdensome task. However, the scientific community decided that it was a task that needed to be done. That's why – in November 2001 – NASA decided that the first mission of its New Frontiers program would be New Horizons.

NASA's New Horizons blasted-off from Cape Canaveral Air Force Station in Florida on 19 January 2006. This sent the spacecraft off on an adventure that continues to yield marvellous results about a region of our Solar System we previously knew very little about. This region, beyond the orbit of Neptune and known as the Kuiper Belt, remains a mystery. This primitive region is littered with icy debris - miniature and ancient planets, rocks and comets. But, its largest and most famous resident is the former-ninth planet – now designated dwarf planet – Pluto and its half-sized moon, Charon.

In the early 2000s elusive Pluto (and the Kuiper Belt) was ranked the number one target for space exploration. One of the reasons why scientists couldn't wait to gather close-up data of the distant dwarf planet was based on the results from the Voyager 2 mission and how they emphasised the uniqueness of a certain Neptunian moon. "Voyager 2 had its flyby of the Neptune system in 1989, and Triton turned out to be the belle of the ball from that. It just wowed people," says Dr Alan Stern, principal investigator of the New Horizons mission. "We already knew that Triton was a captured Pluto-like planet from the Kuiper Belt, so after seeing Triton up close we could hardly wait to get a spacecraft to Pluto."

When launch day arrived everything was in check to make New Horizons the fastest spacecraft propelled into space. The relatively tiny spacecraft measured 0.7-metres (27-inches) tall, 2.1-metres (83-inches) long and 2.7 metres (108 inches) at its widest. Crammed within this package are the finest instruments science and technology could offer at the time of construction, and it weighed in at 478 kilograms (1,054 pounds), which is roughly the same weight as a baby grand piano. A Lockheed Martin Atlas V-551 rocket was used to launch New Horizons, and after the boost from the Boeing STAR-48B third stage, New Horizons became the fastest spacecraft ever launched, as it sped away from Earth at a speed of nearly 58,000 kilometres (36,000 miles) per hour, reaching the Moon's orbit in just nine hours (Apollo took about three days).

In just 13 months, New Horizons had reached Jupiter; the same journey took its New Frontiers sibling, Juno, the best part of five years. The Jupiter flyby was essential for making New Horizons go even faster. "It [the Jupiter flyby] was fundamental in getting to Pluto quickly, because it was a 'gravity assist' flyby. The number one, primary objective was to hit the aim point that directed us to Pluto, and it shaved almost four years off the flight time. That was huge," says Stern. "Had we not have had Jupiter, we would have been arriving at Pluto in 2019, which would have been a much longer and riskier mission."

In this case New Horizons gained nearly 14,000 kilometres (9,000 miles) per hour from this manoeuvre, while simultaneously performing science observations of Jupiter and testing out some of the instruments on board. With the increased speed, New Horizons was placed into hibernation while still hurtling toward Pluto.

This hibernation ended on 6 December 2014, when the team decided to wake New Horizons from its cosmic slumber. The instrument preparation and the long-range observations thus began, and astronomers across the world braced themselves for a historic encounter.

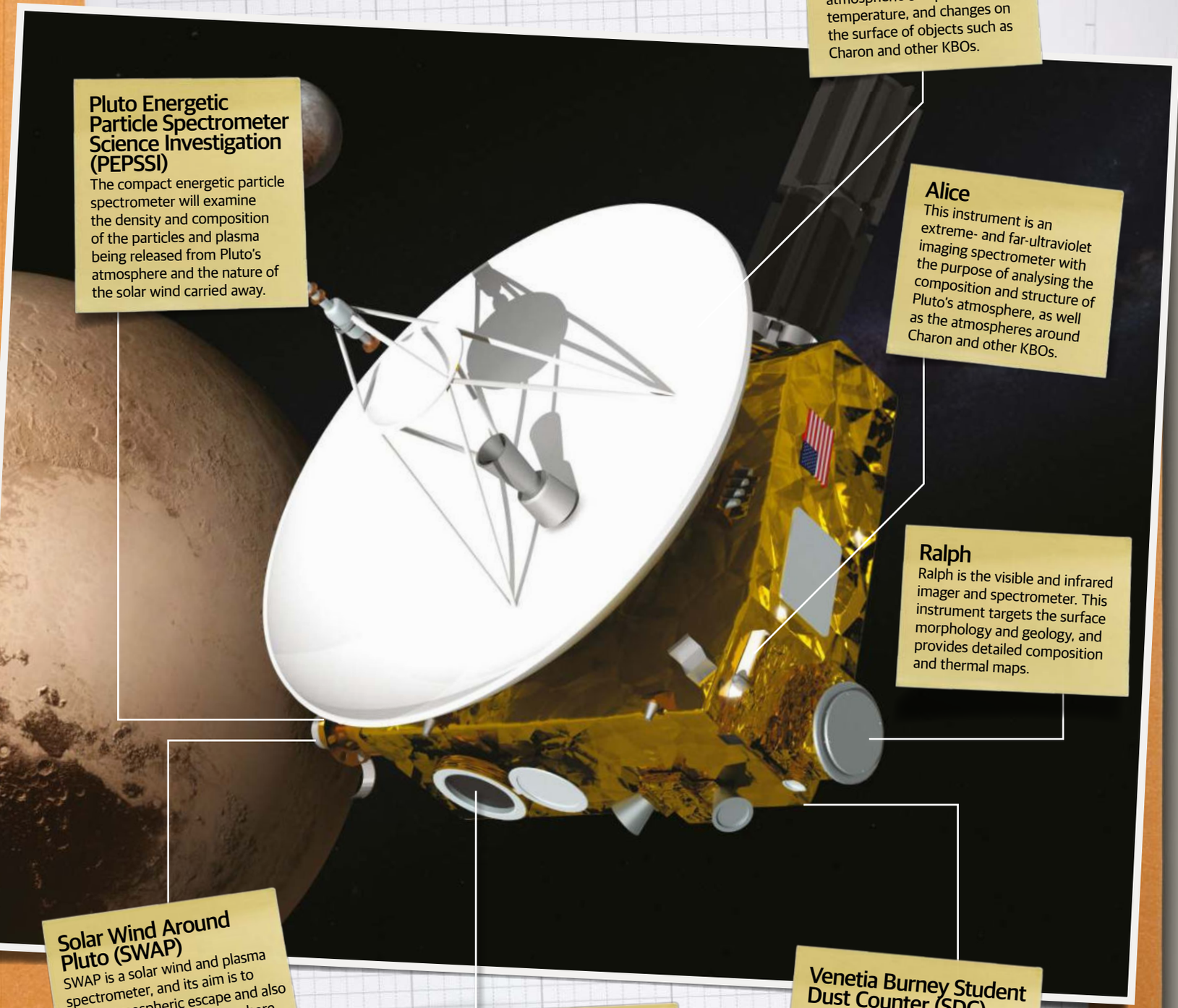
> "After seeing Triton up close we could hardly wait to get a spacecraft to Pluto"
> **Dr Alan Stern**

Then the day finally came. 14 July 2015. After almost a decade and a 4.8 billion kilometre (3 billion mile)-long journey across the vast ocean of nothingness that is space, New Horizons finally arrived at Pluto. The results were incredible; they revealed Pluto's complexity and beauty.

"The two most important discoveries were firstly, the diversity of phenomenology and morphology in the Pluto system. All the bodies there have different personalities, but Pluto broke the mould for how complex a small body can be," explains Stern. "And, secondly, Pluto turned out to be active in its atmosphere, volatile transport and its geology. Active on a massive scale that is unprecedented for anything else we've seen in the Solar System from an object that's barely the size of the United States."

New Horizons managed to get within 12,500 kilometres (7,750 miles) of Pluto and approximately 29,000 kilometres (18,000 miles) of Charon, but the single image that captured the attention of everyone was the most detailed, colour image taken by the Long Range Reconnaissance Imager (LORRI) instrument, revealing the 'heart' of Pluto.

New Horizons' toolkit



Radio Science Experiment (REX)
A passive radiometer that has the capability to measure the atmospheric composition, temperature, and changes on the surface of objects such as Charon and other KBOs.

Pluto Energetic Particle Spectrometer Science Investigation (PEPSSI)
The compact energetic particle spectrometer will examine the density and composition of the particles and plasma being released from Pluto's atmosphere and the nature of the solar wind carried away.

Alice
This instrument is an extreme- and far-ultraviolet imaging spectrometer with the purpose of analysing the composition and structure of Pluto's atmosphere, as well as the atmospheres around Charon and other KBOs.

Ralph
Ralph is the visible and infrared imager and spectrometer. This instrument targets the surface morphology and geology, and provides detailed composition and thermal maps.

Solar Wind Around Pluto (SWAP)
SWAP is a solar wind and plasma spectrometer, and its aim is to study atmospheric escape and also observe how Pluto's atmosphere interacts with solar winds.

Long Range Reconnaissance Imager (LORRI)
The 'eagle eyes' of New Horizons, this high-magnvification imager consists of a telescope with an 8.2-inch aperture that focuses visible light onto a CCD, or charge-coupled device.

Venetia Burney Student Dust Counter (SDC)
(Under spacecraft) An instrument designed and built by students, the SDC measures the concentration of space dust through its entire trajectory towards the outer region of the Solar System.

MISSION PROFILE

Progress report

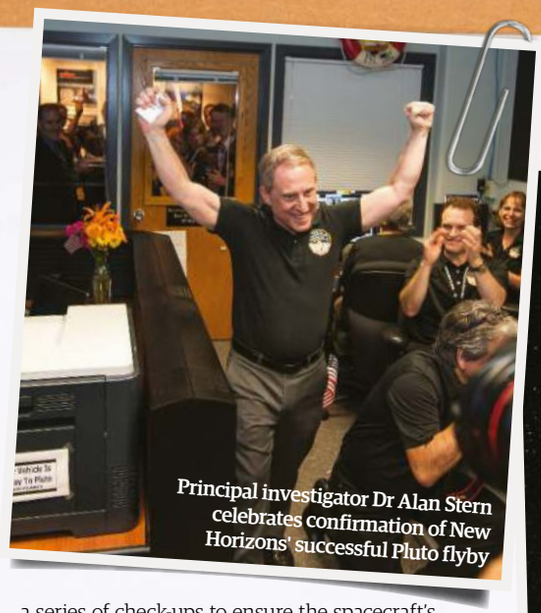
New Horizons continues to make its way through the cold, dark realm that is the Kuiper Belt. With this region being so far away, and the fact there are no current missions in place to return to the Kuiper Belt, the data collected on this mission is extremely precious.

While New Horizons dashes through the cosmos it will be checking out other Kuiper Belt Objects (KBO), as well as taking measurements of the plasma, gas and dust that make up this region. There is one particular KBO that everyone has their sights set on, especially New Horizons. "The next leg of the journey for New Horizons is exploring the Kuiper Belt, and the centrepiece of that is the flyby of Ultima Thule (2014 MU69) on 1 January 2019," says Stern.

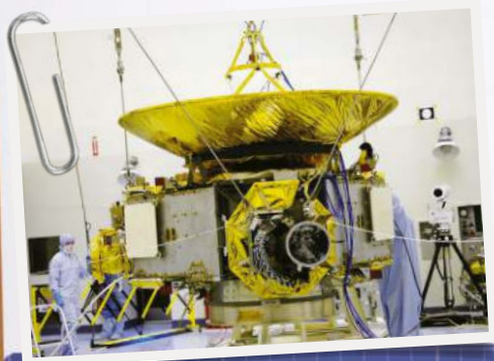
"Compared to what little we knew about Pluto, our knowledge of Pluto before its flyby dwarfs what we know about Ultima. Yet in six-months time, we'll be baring right down on Ultima. And we're going to bring the same scientific firepower of those advanced instruments to this primitive building block for small planets like Pluto."

On the 4 June 2018, New Horizons will wake-up from its hibernation, followed by a series of check-ups to ensure the spacecraft's instruments are in tip-top form ahead of its encounter with Ultima whom is 1.6 billion kilometres (1 billion miles) further than Pluto. What is learnt from this encounter has the potential to completely transform what is known about the essence of our Solar System. These ancient rocks contain the DNA of the early Solar System and by placing them under a microscope, scientists can uncover the many secrets of our origins.

"Currently, we're on a Kuiper Belt exploration mission through 2021. The Ultima data will take a year and a half, maybe two years, to transmit to Earth, even before we can work to figure it out," explains Stern. "All the while, we will be using telescopes and cameras on board New Horizons to study several dozen other Kuiper Belt Objects that we pass in the distance to put Ultima in context."



Principal investigator Dr Alan Stern celebrates confirmation of New Horizons' successful Pluto flyby



"In six-months time, we'll be baring right down on Ultima"

The New Horizons spacecraft was constructed at the Johns Hopkins Applied Physics Laboratory

The past, present and future of New Horizons

6. Arrival at Ultima Thule

Formally known as 2014 MU69, Ultima Thule is New Horizons' next target. The spacecraft is expected to arrive on 1 January 2019 to make 2014 MU69 the most distant object ever visited.

Neptune

Peeping on Pluto

Awakening New Horizons

6 December 2014

New Horizons finally wakes up from its hibernation, and the astronomers can finally begin conducting tests and check-ups in preparation for the Plutonian approach.

Coming into sight

9 April 2015

As Pluto slowly starts coming into focus, New Horizons starts its 'Approach Phase 2' and captures blurred images of the dwarf planet and its largest moon, Charon.

Deciding its trajectory

4 July 2015

The New Horizons team make their final decision to stay on the initial trajectory, other than adopt a Safe Haven By Other Trajectory (SHBOT) path, to avoid accidental collisions.

Prepare for approach

7 July 2017

The core command load engages in the spacecraft and instruments had been tested ahead of its closest approach to the surfaces of Pluto and Charon.

5. Exploring the Kuiper Belt
After the Pluto flyby New Horizons spends its days wondering around the mysterious Kuiper Belt, the region where leftover debris from planet formation remains, getting ready for its next target.

3. The sleeping spacecraft
Soon after the gravity assist at Jupiter, New Horizons was sent into hibernation to preserve its resources due to the longevity of this voyage. This hibernation period lasted about 7.5 years.

2014 MU69

Pluto

2. Jovian gravity assist
In order to make the 4.8-billion-kilometre (3-billion-mile) journey a bit quicker – 3.7 years quicker – New Horizons used Jupiter's gravity to gather more speed and slightly alter its trajectory towards the dwarf planet Pluto.

4. Rendezvous with Pluto
On 14 July 2015, New Horizons finally made its long-awaited approach to the elusive Pluto and its accompanying moons, particularly Charon. This flyby rendered amazing scientific results, uncovering the secrets of these worlds.

Saturn

Jupiter

Mars

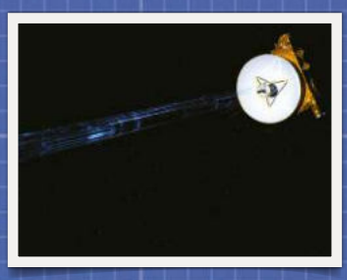
Earth

1. Leaving Earth
On 19 January 2006, the New Horizons spacecraft was launched from Cape Canaveral Air Force Station at a record-breaking speed – a journey that would take over nine years to reach Pluto. It was the first mission launch of NASA's New Frontiers program.

Uranus

Flying by Pluto
14 July 2015
The day finally arrived. In this flyby, New Horizons reached as close as 12,500 kilometres (7,750 miles) from the surface of Pluto, all the while collecting valuable data.

Start data return to Earth
15 July 2015
It will take over 15 months to transmit all of New Horizons' stored data. The final item had to travel 5.5 billion kilometres (3.4 billion miles), which took over five hours to send to Earth.



On to the next target
22 October 2015
The first in a series of manoeuvres to change the spacecraft's trajectory towards Ultima (2014 MU69), signalling the next chapter of New Horizons' voyage into the unknown.

Main objectives

The first reconnaissance of Pluto and its moons
The first step in understanding the outer region of the Solar System is by making the first-ever flyby of the dwarf planet Pluto and its moons, particularly its largest moon Charon.

Kuiper Belt Object flyby
Another groundbreaking flyby will be made on this mission, and that is on 1 January 2019, when New Horizons will make a close flyby of the KBO Ultima Thule, officially named 2014 MU69.

Surveying the Kuiper Belt
This mission will not only closely examine KBOs during its extended mission, but it will continuously be measuring the amounts of charged particles, gas and dust in this particular region.

WOULD YOU MARS

There are many factors to consider when planning to build a Martian colony, from architecture to psychology. Meet the teams who are doing just that

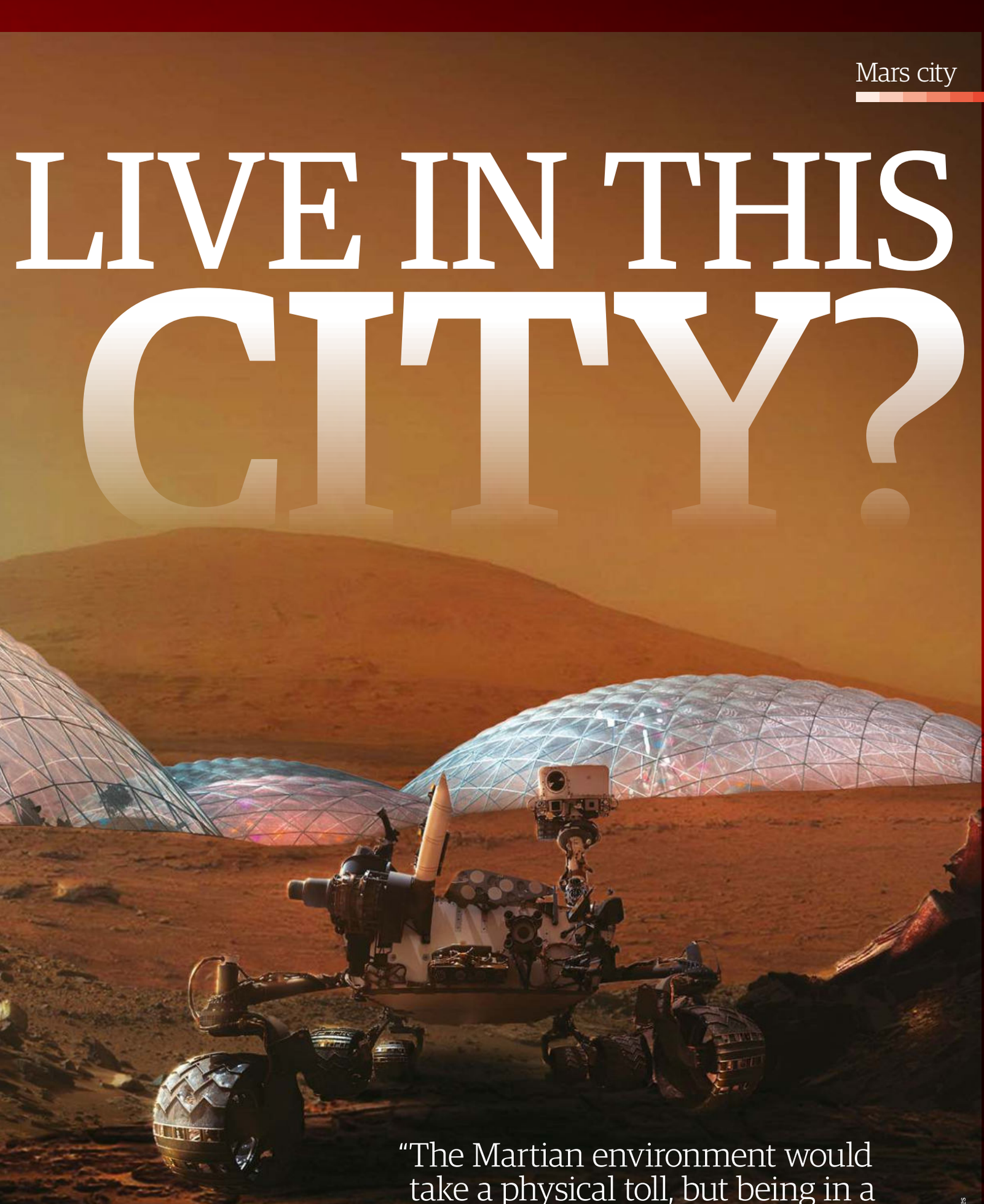
Reported by Lee Cavendish

Humans thrive on exploration, and while our race has explored virtually everything there is to offer on Earth, the urge to go further persists. This is why billions of people across the globe wish to break the boundaries of Earth and explore our neighbouring planet, Mars. Big names such as NASA, SpaceX and Virgin Galactic are all making huge steps in getting humans into space in a spacecraft that is capable of making the minimum 54.6-million-kilometre (33.9-million-mile) voyage. But what is to happen to the group of pioneers once they actually arrive?

With over two decades of close surveillance of Mars, courtesy of an array of orbiters, landers and rovers, scientists now know that the surface of Mars is a dry, cold and cruel environment for humans. If humans were to survive on Mars they would have to be protected in a confined sanctuary. The Martian environment would take a physical toll on its inhabitants due to its less intense gravity and sunlight, but being in a confined and isolated facility could take a large psychological toll too.

Given that the success of a mission can be affected by the physical and psychological health of its crew members, space agencies are getting increasingly creative in their approach – without leaving Earth. One such experiment – Mars-500 – was run by the Russian Institute for Biomedical Problems and the European Space Agency. The experiments were conducted between 2007 and 2011 in Moscow, Russia. Its aim was to understand the effects of future manned missions on man by isolating six people in a 'spacecraft' for 520 days, as if they were making the return journey to Mars.

LIVE IN THIS CITY?



"The Martian environment would take a physical toll, but being in a confined and isolated facility could take a large psychological toll too"

Meet Mars-500

The Mars-500 crew spent 520 days isolated in a facility located in Moscow, Russia

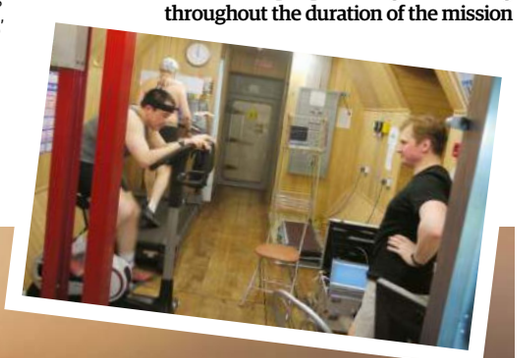
The study was divided into three stages: firstly, a short 14-day simulation in order to test the facilities and operational procedures, followed by a 105-day isolation study undertaken with six crew members of Russian and European origin. In the final stage, six international crew members participated in a full 520-day isolation study, which included a simulated Mars landing and three 'Mars-walks'.

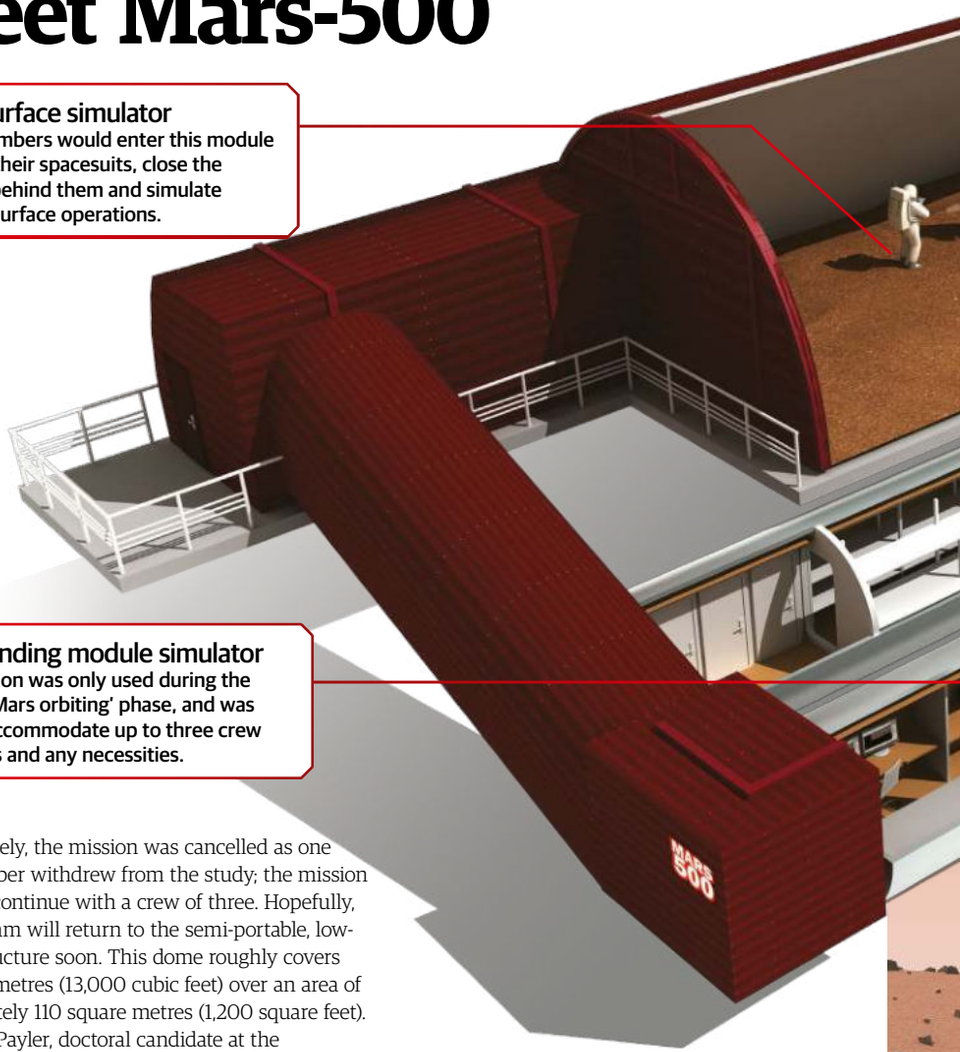
The purpose of this experiment was to gain valuable information about the psychological and physiological changes that may occur in participants during a long-term mission to Mars. The experiments yielded very interesting results regarding the crew members' activity and sleep levels. It was found that as the days wore on, the crew were more interested in their beds! In fact, on the 'return journey' to Earth, the crew spent nearly 700 hours longer in bed than the 'journey to Mars'. It was only in the last 20 days that the crew perked up, before 'returning' to Earth on 4 November 2011.

Less than 18 months after the end of Mars-500, a new simulation research project, the Hawaii Space Exploration Analog and Simulation (HI-SEAS), led by the University of Hawaii at Mānoa, and funded by NASA commenced. The HI-SEAS habitat is located some 2,500 metres (8,200 feet) above sea-level, atop the Mauna Loa volcano in Hawaii; it is the closest Mars-like environment we have on Earth. Its dry and almost lifeless scenery resembles Mars and, when combined with the HI-SEAS crews' delayed communications, partial self-sufficiency and enclosed habitat, makes a prime experiment for identifying the factors required for a successful long-duration planetary surface mission.

There have been five missions completed so far, and a sixth had begun in February 2018.

This city will be the largest space-simulation city ever built





Unfortunately, the mission was cancelled as one crew member withdrew from the study; the mission could not continue with a crew of three. Hopefully, another team will return to the semi-portable, low-impact structure soon. This dome roughly covers 370 cubic metres (13,000 cubic feet) over an area of approximately 110 square metres (1,200 square feet).

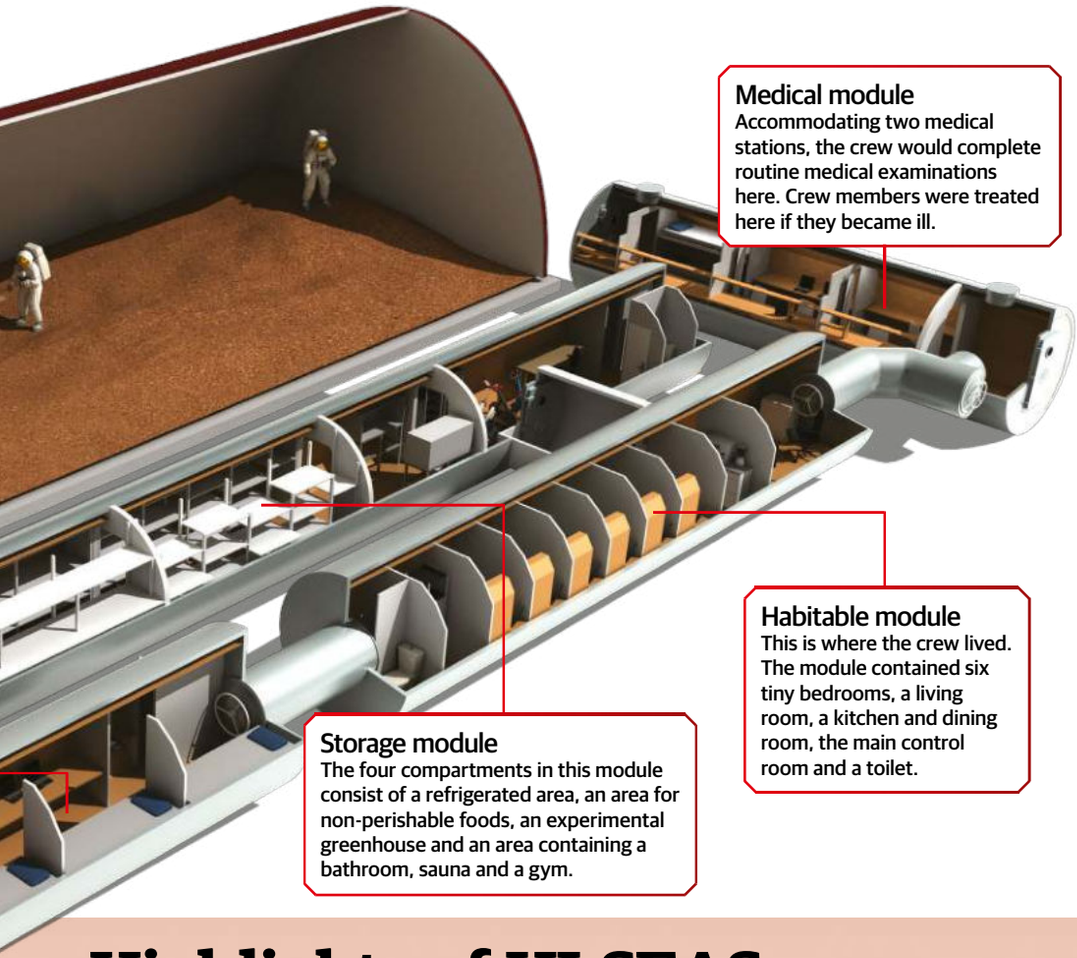
Samuel Payler, doctoral candidate at the University of Edinburgh and science officer of HI-SEAS mission V, explains to **All About Space** the aims of the mission: "The goal of HI-SEAS is to understand what you have to go for in the crew composition to ensure the crew cooperate. You have to ask questions like: how do you pick your team of astronauts? What [characteristics] do you look for in them? What will picking certain things result in?

The Mars 500 crew kept up with regular training throughout the duration of the mission

"This is intended to produce the most cohesive and productive team together for Mars, especially when you spend billions and billions of pounds on getting there. You don't want the team to fight and not be productive."

Looking toward the future, the United Arab Emirates (UAE) announced plans to build the largest ever space-simulation city just last year. The £100 million ($140 million) project, dubbed the Mars Science City, will cover a humongous 177,000 square metres (1.9 million square feet) in the Emirati desert in Dubai. To put that into perspective, that is over 1,600-times larger than the HI-SEAS habitat. This incredible structure comes as part of the UAE's 'Mars 2117 Strategy', aiming to build the first settlement on Mars in the next 100 years.

The uniqueness of the Mars Science City cannot be understated; the innovative advantages of this structure are like nothing ever seen before, and it will be vital to how we build a settlement on Mars. This building will harness its environment by using



Medical module
Accommodating two medical stations, the crew would complete routine medical examinations here. Crew members were treated here if they became ill.

Habitable module
This is where the crew lived. The module contained six tiny bedrooms, a living room, a kitchen and dining room, the main control room and a toilet.

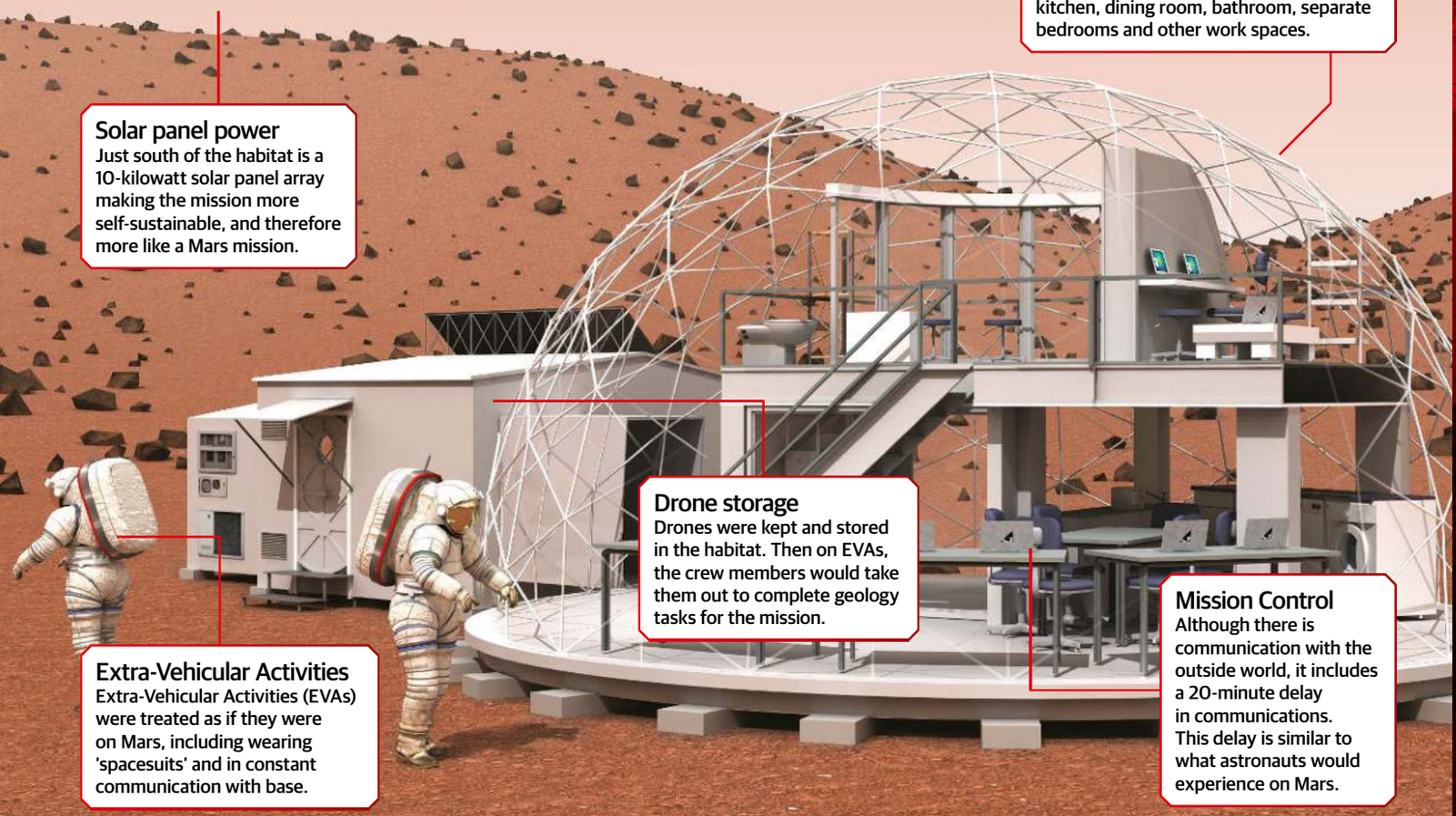
Storage module
The four compartments in this module consist of a refrigerated area, an area for non-perishable foods, an experimental greenhouse and an area containing a bathroom, sauna and a gym.

the surrounding desert sand to 3D print the walls of its future in-built museum. This efficiency will be essential when it comes to erecting a sanctuary on Mars, as it means that the raw materials won't have to travel on the spacecraft, saving fuel or making room for more important items or supplies.

The Mars Science City will also include an experimental aspect that will involve a team living in this simulated Mars city for one year. Although it differs from the previous psychological and physiological objectives that Mars-500 and HI-SEAS were tackling, the Mars Science City experiments will hope to improve upon the self-sustainability in energy, water and food – the essentials for life.

The collective ambitions of these projects, lest we forget the constant variety of experiments being conducted on the International Space Station, all have one common goal in mind, and that is to finally get humans on to, and eventually colonise, another planet. The task is arduous, there is no doubt about that, but it is possible. However, it is only possible as a collaborative effort, and that involves the development of a habitat that manipulates the Martian environment to our needs. Not only that, but the interaction of the crew is of the utmost importance to ensure a high work rate and efficiency. By gaining a collective insight on what it's like to travel to Mars, build a structure there and then survive there, the human race gets ever closer to the dream of a 'Mars City'.

Highlights of HI-SEAS



The home dome
The habitat dome was supplied by Pacific Domes International, which includes a kitchen, dining room, bathroom, separate bedrooms and other work spaces.

Solar panel power
Just south of the habitat is a 10-kilowatt solar panel array making the mission more self-sustainable, and therefore more like a Mars mission.

Drone storage
Drones were kept and stored in the habitat. Then on EVAs, the crew members would take them out to complete geology tasks for the mission.

Extra-Vehicular Activities
Extra-Vehicular Activities (EVAs) were treated as if they were on Mars, including wearing 'spacesuits' and in constant communication with base.

Mission Control
Although there is communication with the outside world, it includes a 20-minute delay in communications. This delay is similar to what astronauts would experience on Mars.

STARGAZER

In this issue...

What's in the sky?

27 MAY
Conjunction between the Moon and Jupiter in Libra

28 MAY
Globular cluster Messier 4 (NGC 6121) is well placed for observation in Scorpius

3 JUN
Conjunction between the Moon and Mars in Capricornus

5 JUN
Messier 10 (NGC 6254) is well placed for observation in Ophiuchus

6 JUN
Globular cluster Messier 62 (NGC 6266) is well placed for observation in Ophiuchus

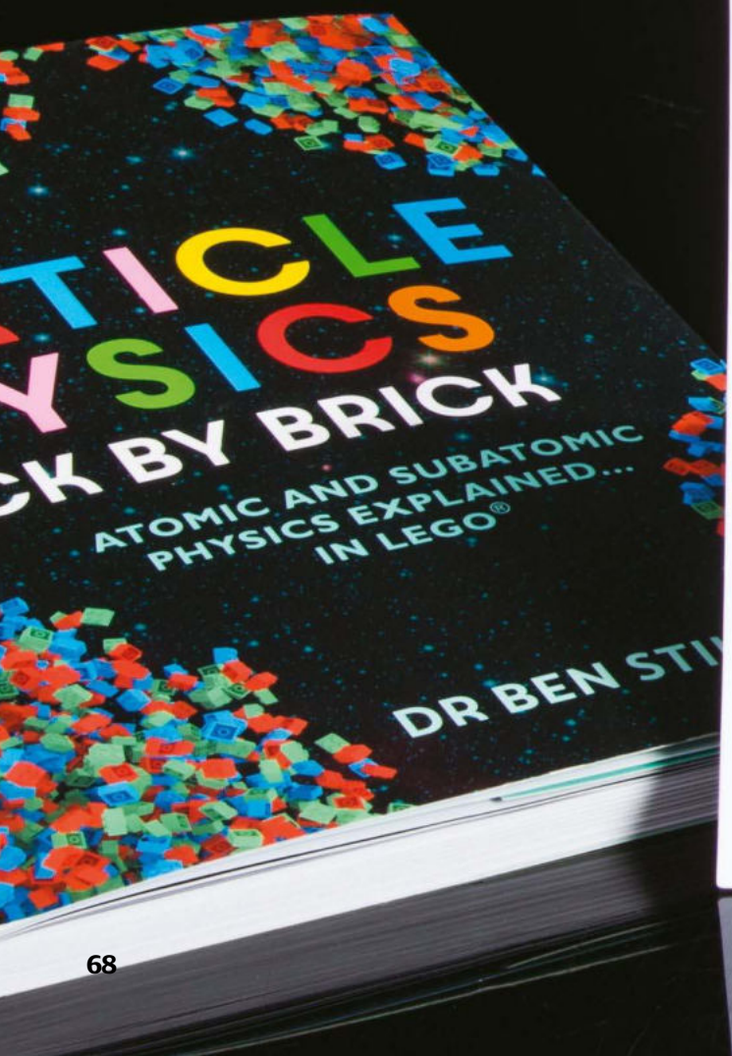
15 JUN
Globular cluster NGC 6388 is well placed for observation in Scorpius

15 JUN
Asteroid 29 Amphitrite is well placed for observation in Scorpius

16 JUN
Butterfly open cluster (Messier 6) is well placed for observation in Scorpius

18 JUN
Open cluster IC 4665 is well placed for observation in Ophiuchus

20 JUN
The Ophiuchuds reach their peak of five meteors per hour



Jargon buster

Conjunction
A conjunction is an alignment of objects at the same celestial longitude. The conjunction of the Moon and the planets is determined with reference to the Sun. A planet is in conjunction with the Sun when it and Earth are aligned on opposite sides of the Sun.

Right Ascension (RA)
Right Ascension is to the sky what longitude is to the surface of the Earth, corresponding to east and west directions. It is measured in hours, minutes and seconds since, as the Earth rotates on its axis, we see different parts of the sky throughout the night.

Declination (Dec)
This tells you how high an object will rise in the sky. Like Earth's latitude, Dec measures north and south. It's measured in degrees, arcminutes and arcseconds. There are 60 arcseconds in an arcminute and there are 60 arcminutes in a degree.

Magnitude
An object's magnitude tells you how bright it appears from Earth. In astronomy, magnitudes are represented on a numbered scale. The lower the number, the brighter the object. So, a magnitude of -1 is brighter than an object with a magnitude of +2.

Opposition
When a celestial body is in line with the Earth and Sun. During opposition, an object is visible for the whole night, rising at sunset and setting at sunrise. At this point in its orbit, the celestial object is closest to Earth, making it appear bigger and brighter.

Greatest elongation
When the inner planets, Mercury and Venus, are at their maximum distance from the Sun. During greatest elongation, the inner planets can be observed as evening stars at greatest eastern elongations and as morning stars during western elongations.

1 JUN
Conjunction between the Moon and Saturn in Sagittarius

2 JUN
The Hercules globular cluster (Messier 13) is well placed for observation in Hercules

3 JUN
Globular cluster Messier 12 (NGC 6218) is well placed for observation in Ophiuchus

10 JUN
The Ophiuchuds reach their peak of five meteors per hour

10 JUN
Globular cluster Messier 92 (NGC 6341) is well placed for observation in Hercules

16 JUN
Globular cluster NGC 6397 is well placed for observation in Ara

16 JUN
Conjunction between the Moon and Venus in Cancer

16 JUN
Asteroid 9 Metis is well placed for observation in Ophiuchus

20 JUN
The Ptolemy Cluster (Messier 7) is well placed for observation in Scorpius

20 JUN
Asteroid 4 Vesta is well placed for observation in Sagittarius

- Naked eye
- Binoculars
- Small telescope
- Medium telescope
- Large telescope

STARGAZER

Planetarium 06 June 2018

Moon calendar

* The Moon does not pass meridian on 28 May

24 MAY	25 MAY	26 MAY	27 MAY
77.9%	86.2%*	92.7%	97.1%
03:19 15:10	03:42 16:21	04:05 17:32	04:29 18:40

28 MAY	29 MAY	30 MAY	31 MAY	1 JUN	2 JUN	3 JUN
--.-*%	FM 99.5%	99.7%	97.9%	94.2%	88.9%	LQ 82.1%
04:55 19:47	05:24 20:52	05:57 21:52	06:37 22:46	07:22 23:34	08:13 --:--	00:15 09:10

4 JUN	5 JUN	6 JUN	7 JUN	8 JUN	9 JUN	10 JUN
74.0%	65.0%	TQ 55.3%	45.1%	34.8%	24.9%	15.8%
00:50 10:10	01:19 11:13	01:45 12:18	02:09 13:25	02:32 14:34	02:54 15:45	03:18 17:00

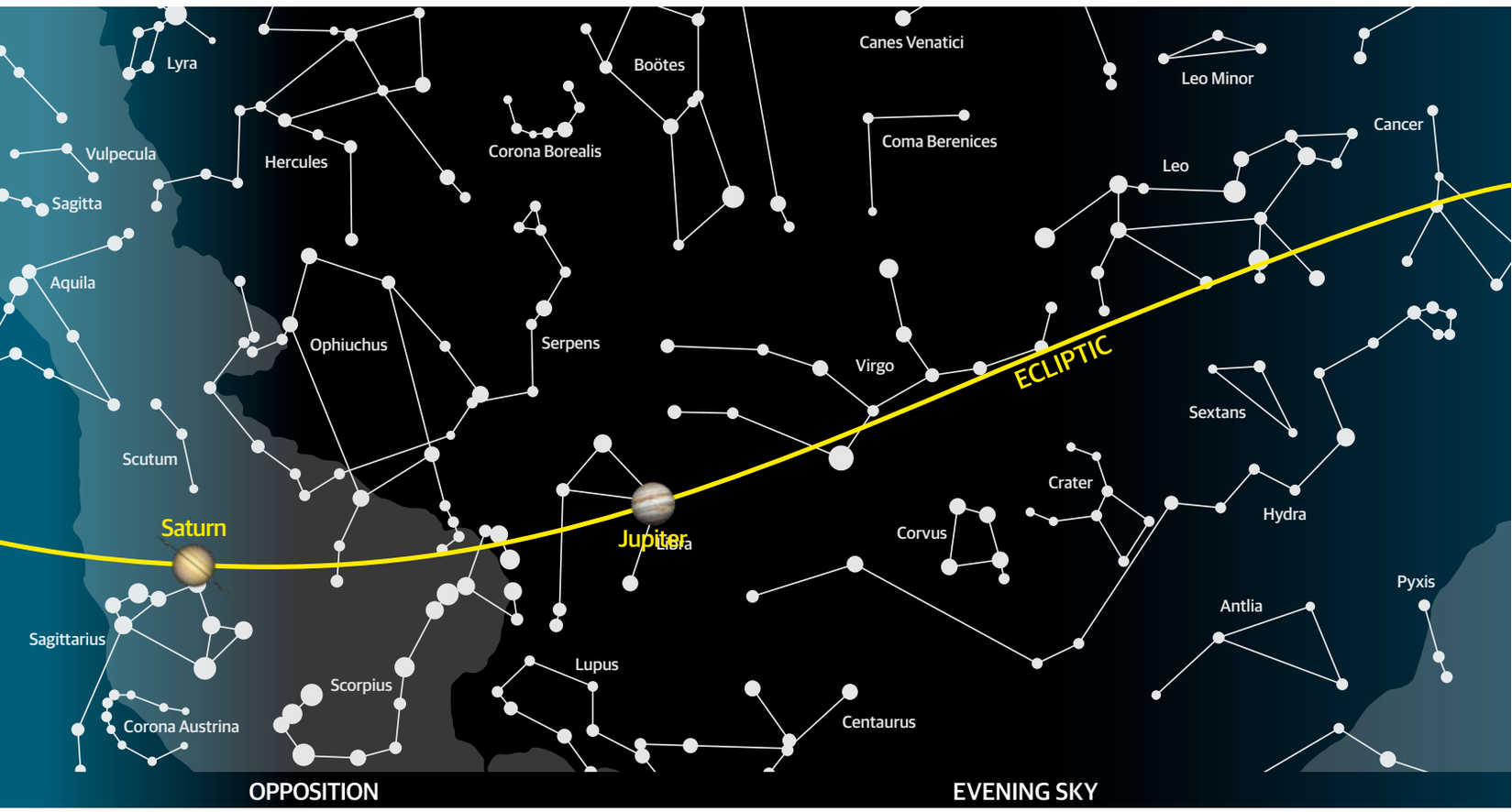
11 JUN	12 JUN	13 JUN	14 JUN	15 JUN	16 JUN	17 JUN
8.3%	2.9%	NM 0.3%	0.8%	4.6%	11.3%	20.4%
03:45 18:17	04:17 19:35	04:56 20:51	05:45 22:00	06:44 23:00	07:54 23:48	09:10 --:--

18 JUN	19 JUN	20 JUN	21 JUN
30.9%	42.2%	FQ 53.6%	64.5%
00:26 10:28	00:58 11:45	01:25 13:00	01:49 14:12

% Illumination
Moonrise time
Moonset time

FM Full Moon
NM New Moon
FQ First quarter
LQ Last quarter

All figures are given for 00h at midnight (local times for London, UK)



Illumination percentage

	30 MAY	06 JUN	13 JUN	20 JUN
MERCURY	90%	100%	90%	80%
VENUS	80%	80%	80%	70%
MARS	90%	90%	90%	90%
JUPITER	100%	100%	100%	100%
SATURN	100%	100%	100%	100%

Planet positions

All rise and set times are given in BST

	Date	RA	Dec	Constellation	Mag	Rise	Set
MERCURY	24 May	03h 02m 57s	+15°40'58"	Aries	-0.8	04:28	19:22
	30 May	03h 50m 47s	+19°37'10"	Taurus	-1.4	04:28	20:10
	06 Jun	04h 54m 09s	+23°18'14"	Taurus	-2.4	04:39	21:11
	13 Jun	06h 00m 29s	+25°04'12"	Taurus	-1.4	05:04	22:03
	20 Jun	07h 02m 06s	+24°39'37"	Gemini	-0.8	05:41	22:33
VENUS	24 May	06h 22m 23s	+25°02'51"	Gemini	-4.0	06:45	23:43
	30 May	06h 53m 48s	+24°43'28"	Gemini	-4.0	06:55	23:48
	06 Jun	07h 29m 52s	+23°49'30"	Gemini	-4.0	07:10	23:50
	13 Jun	08h 05m 01s	+22°23'49"	Cancer	-4.0	07:28	23:47
	20 Jun	08h 39m 02s	+20°29'26"	Cancer	-4.0	07:47	23:41
MARS	24 May	20h 21m 55s	-21°55'00"	Capricornus	-1.0	01:12	09:18
	30 May	20h 30m 18s	-21°48'07"	Capricornus	-1.2	00:56	09:04
	06 Jun	20h 38m 34s	-21°46'00"	Capricornus	-1.4	00:37	08:44
	13 Jun	20h 44m 56s	-21°51'59"	Capricornus	-1.6	00:16	08:23
	20 Jun	20h 49m 07s	-22°07'28"	Capricornus	-1.8	23:50	07:58
JUPITER	24 May	14h 56m 33s	-15°30'20"	Libra	-2.5	19:04	04:33
	30 May	14h 53m 49s	-15°19'31"	Libra	-2.5	18:37	04:08
	06 Jun	14h 50m 57s	-15°08'16"	Libra	-2.4	18:05	03:38
	13 Jun	14h 48m 29s	-14°51'42"	Libra	-2.4	18:05	03:38
	20 Jun	14h 46m 30s	-14°51'42"	Libra	-2.4	17:04	02:40
SATURN	24 May	18h 34m 09s	-22°19'12"	Sagittarius	0.2	23:23	07:28
	30 May	18h 32m 42s	-22°20'33"	Sagittarius	0.2	25:58	07:03
	06 Jun	18h 30m 49s	-22°22'16"	Sagittarius	0.1	22:29	06:33
	13 Jun	18h 28m 46s	-22°24'05"	Sagittarius	0.1	22:00	06:03
	20 Jun	18h 26m 37s	-22°25'58"	Sagittarius	0.1	21:30	05:33

DAYTIME ASTRONOMY

Forget staying up late, **All About Space** shows you how to get stuck into observing without waiting until the small hours

Written by Stuart Atkinson

When most think of astronomy they picture someone standing outside on a sparkling clear night, gazing up at the wonders of the universe, perhaps using a telescope or pair of binoculars, or just sweeping the night sky with their eyes, taking in the view of stars, planets, the Milky Way and other natural nocturnal wonders. Indeed, a Google image search for "astronomy" will bring up hundreds, even thousands, of pictures of people standing on their own, or in a small group, peering into telescopes beneath a star-dusted sky long after the rest of the world has gone to bed.

As the old joke goes, astronomy is the perfect hobby for three types of people: insomniacs, burglars and vampires. But astronomy doesn't have to be such an anti-social pastime, and it doesn't have to be done between sunset and sunrise either.

It's possible to do astronomy in the daytime – in fact, it's a good idea for every stargazer and sky-watcher to know what there is to see in the daytime sky because those aforementioned sparkling clear nights are few and far between, and when they eventually arrive our view of celestial phenomena and events is often spoiled because of light pollution. So, what can you see in the daytime sky?

TARGET #1

The Sun

While it's our nearest star, the Sun can be a challenging target without the equipment – read on for essential tips and tricks

The most obvious thing to look for and study in the daytime sky is, of course, the Sun. One of the very first things that someone 'getting into' astronomy learns – and is amazed by – is that the bright white ball they have seen shining brightly in the sky above them all their lives is in fact a star, the closest star to the Earth. The night sky is full of distant suns, each tiny, twinkling dot a star like our own. Well, not exactly like it; some stars are bigger than our Sun, some are smaller. Some are hotter, some are cooler. However, like all the stars in the night sky, our Sun is an enormous, hot ball of gas that keeps burning through the process of nuclear fusion, providing us here on Earth with the light, heat and energy we need to survive. And because the Sun is a star, when you look at it you are definitely doing astronomy.

The good news for anyone wanting to observe the Sun is that it is much closer than almost every other astronomical object. Just 146 million kilometres (90 million miles) away, it is nearer to the Earth than everything except the Moon and a couple of Earth's sister planets. Its close proximity means we are able to see and study it in great detail from here on Earth – but only if we use the right equipment. The Sun is incredibly bright, and it is

Solar projection is a great way to view sunspots and solar eclipses

"The good news for anyone wanting to observe the Sun is that it is closer than almost every other astronomical object"

TARGET #2

The planets

It is sometimes possible to see planets in the daytime sky, but only if you have very good eyesight, you know exactly where to look for them and at what time of day, if they are well away from the Sun and the sky is very clear with no distracting clouds.

The planet most easily seen in the daytime sky is Venus because it is the brightest. When it is at its farthest point from the Sun, keen-eyed people can sometimes pick Venus out from the blue sky as a spark of silvery light. Others need binoculars to find it. Be careful, though, as you should never look for it, or any other planet, without hiding the Sun behind a building or hill so you don't accidentally look at it while planet hunting.

View sunspots the easy way

You can observe sunspots – magnetic storms on the surface of the Sun – safely by projecting an image of the Sun on to a paper or card screen using just a pair of binoculars. If you have a clear view of the Sun for several days in a row you can watch how the sunspots change their shape and size as they are carried across the Sun's face by its rotation.

1 Select a piece of white paper or card to use as a screen – make sure it is very clean, without any patterns or blemishes.

2 Cover up one of the objective (front) lenses of the binoculars so only one image will be projected instead of two.

3 Position your screen behind the binoculars.

4 Align your binoculars with the Sun by holding them towards it and moving them around until a bright circle appears on the screen behind them. Do not look through the binoculars at any time.

5 Sharpen the Sun's image by turning the focusing wheel on the binoculars.

6 Adjust the size of the projected image of the Sun by moving the binoculars and screen apart.

7 If there is any sunspot activity on the Sun you will see the sunspots as small dark markings on the bright solar disc.

8 If you can view the sunspots for several days in a row you will be able to see them change shape and size as they are carried across the Sun's face by the rotation of the Sun.

9 Even if there are no sunspots visible on the Sun when you look, check for any large sunspot groups just coming into view on the edge of the Sun. They will be better placed for viewing on subsequent days.

so bright because it is so hot: on its surface the temperature is a stunning 6,000 degrees Celsius (10,832 degrees Fahrenheit), and its core is even hotter. That means anyone wanting to observe the Sun has to take extraordinary care, and use special equipment and techniques, or else they risk serious eye injury or even permanent blindness. However, with the right gear, and a healthy amount of caution and common sense, our closest star can be a fascinating object to study before the more distant stars come out.

One simple and safe way of observing the Sun is to simply look at how its shape and colour changes through the day, depending on how much cloud it is shining through, how high it is in the sky and so on. When the Sun is high in the sky, or overhead, it is an eye-wateringly bright object. When the Sun is about to set, or has just risen, and is low in the sky it can appear bigger, bloated and more orange in colour than when overhead. This is because we are looking at it through more of the atmosphere, so its light is refracted and distorted, making it appear squashed and bloodshot, and a lot less bright, too. But even when it is low and dim you still have to be very careful not to look directly at it for more than a moment, or you will risk damage to your eyes.

Because it has always just looked like a bright, blank white disc in the sky, newcomers to astronomy are often amazed to learn that there are fascinating features to be seen on the face of the Sun, and they want to see them! However, to see dramatic solar features such as sunspots, prominences and flares you have to find a way to magnify the Sun's disc, which is surprisingly small. It's easy to magnify the Moon or objects in the night sky – all you have to do is look at them through a pair of binoculars or a telescope. But if you use those instruments on the Sun you will concentrate its light and heat into intense beams that will cook your eyes like fried eggs. However, with the right equipment and techniques it is possible to enjoy stunning views of the Sun perfectly safely.

The easiest way is to use Solar Projection. This involves – as its name suggests – projecting an image of the Sun on to a suitable surface and studying that image instead of looking directly at the Sun itself. To project a solar image you will need either a pair of binoculars or a small telescope, and a piece of white paper or card to place behind them to use as a screen. By carefully positioning the binoculars or telescope between the Sun and the screen at just the right angle so the Sun's rays go straight through their lenses and form an image on the screen, you will produce an image of the Sun large enough to show any dark sunspots on its face at that time. Sometimes the Sun is completely blank, so don't worry if you can't see anything the first time you look! You can change the size and sharpness of the image by moving the screen closer to or further away, and by focusing it in the usual way.

Using projection you can watch sunspots as they appear from around the limb then follow them as they track across the disc, changing shape and size. The advantages of using solar projection to observe the Sun are many. It is very simple, very quick and cheap too. It also means several people can see the Sun at the same time. However, it is absolutely vital you don't look through the projecting equipment or let your skin or anything else wander into the path of the light. Remember how you used to burn paper with the Sun and a magnifying glass when you were younger? Solar projection works on the same principle, so be very, very careful.

It might seem pretty obvious that if you want a more detailed view of the Sun you will need to

A projection can be shared with many people at once, making it a more social form of astronomy

TARGET #3

Iridium flares

For years many sky-watchers and stargazers have enjoyed spotting the bright flares from the solar panels of Iridium satellites. The brightest can outshine everything in the sky apart from the Sun and the Moon, appearing as a dazzlingly bright point of light that fades after a few seconds. The brightest of these can be seen in the daytime if you know exactly where and when to look. Apps for smartphones and tablets and websites will tell you when and where you have a chance of seeing one, but you'll have to be quick; the imminent retirement of the Iridium satellites means there will be no more flares happening by the end of the year.

"Using projection you can watch sunspots as they appear from around the limb then follow them"

magnify it more - but how, if looking directly at the Sun through a telescope is dangerous? The solution is to fit your telescope with a special filter which reduces its brightness to a fraction of a percent of its usual brightness, then you can use your telescope and eyepieces to zoom in on its surface features just as you would zoom in on lunar craters, star clusters or the planets.

The most common and popular type of solar filter is the Mylar filter. Mylar is a very special material that looks deceptively like silver kitchen foil or the material helium balloons are made of, but is in fact a very dense, very lightweight specialised material astronomers have been using for decades now. You can either buy a ready-made Mylar filter produced specifically for your telescope make, model and size, or you can send off for a small sheet of the

A Mylar filter can turn any telescope into a solar instrument

Watch the Sun live

If you don't have the special filters or expensive telescopes amateur astronomers use to observe and study the Sun don't worry, you can still keep an eye on it – even if the sky is cloudy! There are now free apps for smartphones and tablets that let you explore the Sun and monitor its activity. You will find them with a quick search on your app store. If you don't have a smartphone or device you can do the same thing via the website of NASA's Solar Dynamics Orbiter Sun watching observatory.

1 Go to the SDO website using your web browser: **sdo.gsfc.nasa.gov**.

2 Select the menu bar at the top right.

3 Select 'Data' from the following menu.

4 Select 'The Sun Now' from the next menu.

5 When 'The Sun Now' is highlighted in blue, scroll down the page to view images of the Sun taken at different wavelengths.

6 First select the view of the Sun in Hydrogen-alpha by scrolling down to the image labelled 'AIA 304'. This will allow you to see any prominences on the edge of the Sun. The Sun's disc will appear a deep-red or deep-orange colour.

7 If you see any crimson loops, arches or feathery towers suspended above the limb of the Sun these are prominences. Zoom in on them to see more details.

8 Look out for any bright spots or squiggles on the Sun's face. These might be very powerful solar flares.

9 To see the Sun in 'white light' scroll down to the views labelled 'HMI Intensitygram'. There are three different ones. All show the view you would have of the Sun if you were projecting its image. These images of the Sun appear gold, yellow and white. The colours don't really matter. These views will allow you to see any sunspot activity on the Sun at that time. They will look like small dark spots.

10 Zoom in on any sunspots visible so you can see their structure more clearly. Look out for the very dark centre 'umbra' region and the lighter, streaked 'penumbra' that surrounds it.

11 You can use the website to view movies showing recent solar activity. Click on a link that says 'MPEG' and a file will be downloaded to your computer. It will let you watch sunspots coming into view over the limb of the Sun several days earlier, and show they have changed shape and size since then. They will also show you prominences forming and falling away again.

"Should you see a brief flash of pink or white you'll have been lucky enough to witness a rare solar flare"

TARGET #4

Solar and lunar Space Station transits

Spotting the International Space Station (ISS) is now a very popular part of amateur astronomy - and many of you reading this would be thrilled at the sight of the ISS sailing silently across the sky, shining like a bright star. On very rare occasions the ISS' path across the sky takes it between us and the Moon or the Sun, and for a couple of seconds it can be seen silhouetted against it. To catch one of these transits you have to be in exactly the right place at exactly the right time, as predicted by phone apps or websites. You also need a telescope to be able to see the tiny silhouette of the ISS, fitted with a solar filter, of course, if it is transiting the Sun.

material and then make your own filter using a hoop of strong cardboard that pushes over the front of your telescope. There are lots of solar filter-making guides available online, or from your local astronomical society.

Using a Mylar solar filter means you can magnify the Sun dozens or even hundreds of times, allowing you to see some very fine detail within and around sunspots, and see how they change shape over time, with areas appearing and disappearing, different small groups of spots joining up to make larger groups and more. You will also be able to see the 'granulation' of the Sun's surface, which many people think looks like the outer peel of an orange seen through a magnifying glass.

Solar filters are safe as long as they are made of the correct material (be very careful not to buy cheap filters online which may be made from material that will not protect your eyes), fitted properly and are not suffering from wear and tear – any holes or scratches, however small, could let sunlight into your eyes and damage them. The main drawbacks with solar filters are their expense compared to simply using projection, and the way that they only allow one person to view the Sun at a time.

There are more than just dark sunspots on the Sun's surface, but if you want to see the spectacular loops and arches of fiery gas known as prominences, and glimpse bright solar flares you will need to dig deeper into your pockets.

If you want to see everything the Sun has to offer you will need to invest in, or borrow, a special solar telescope. These instruments are very specialised (hence expensive) pieces of equipment featuring built-in filters which are tuned specifically to the 'Hydrogen-alpha' wavelength. Viewed in H-alpha the face of the Sun is transformed from a blank, featureless disc to a sunspot-spattered cauldron. If there are any present at the time of viewing, prominences will look like fiery arches, loops or hoops on the Sun's edge, and should you see a brief flash or flaring of pink or white on the disc you'll have been lucky enough to witness a rare and powerful solar flare just as it happened.

Solar telescopes offer stunning, detailed views of our nearest star but they are very expensive, and many people find them difficult to get to grips with. An alternative would be to buy a Hydrogen-alpha filter to go over the front of your telescope, but these are very expensive too.

If you want to see this kind of detail on the Sun but can't afford or don't have access to any of the equipment detailed above don't worry! There are many free apps available for your smartphone or tablet, and websites you can visit which show 'live' views of the Sun in optical and other wavelengths. You can use them to see how spotty the Sun is and watch prominences leap off the Sun and fall back down again.

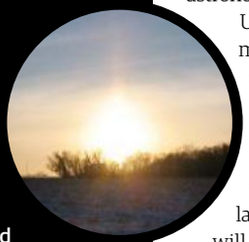
TARGET #5

Lunar planetary occultations

Very rarely it is possible to see a planet disappearing behind – or emerging from behind – the curved limb of the Moon. Just like ISS transits, you have to be in the right place at the right time to see one of these planetary occultations, and will also need either a pair of binoculars or a telescope to see it. If you have patience and time things just right the view, and the experience, can be amazing.

Naked-eye solar effects

Sun dogs



Sun dogs, known more scientifically as 'parhelia', look like miniature rainbows on either side of the Sun when it is low in the sky, either just before it sets or just after it has risen. They are caused by the Sun's light being refracted and reflected by ice crystals in the upper atmosphere, between five and ten kilometres (three and six miles) above Earth's surface.

Solar halo

A solar halo is, as its name suggests, a glowing halo around the Sun. All solar haloes have a radius of 22 degrees. Solar haloes are usually seen when the Sun is high in the sky and are caused by ice crystals high in the atmosphere refracting and bending the Sun's light. Some solar haloes are quite dim, little more than a pale grey-white circle around the Sun. The most dramatic haloes are very eye-catching, taking the form of a beautiful blue-white ring around the Sun, or even rainbow-hued. You'll notice that the sky inside the halo is darker than the sky outside of it.

Sun pillar

If plate-shaped ice crystals in the upper atmosphere line up in a certain way a column of silvery-blue or sometimes golden light can appear above the Sun, but only when it is at a low altitude, not when it is high in the sky. This is known as a 'Sun pillar', for obvious reasons, and they often linger in the sky after the Sun has set or herald its appearance before it has actually risen.

Circumzenithal arc

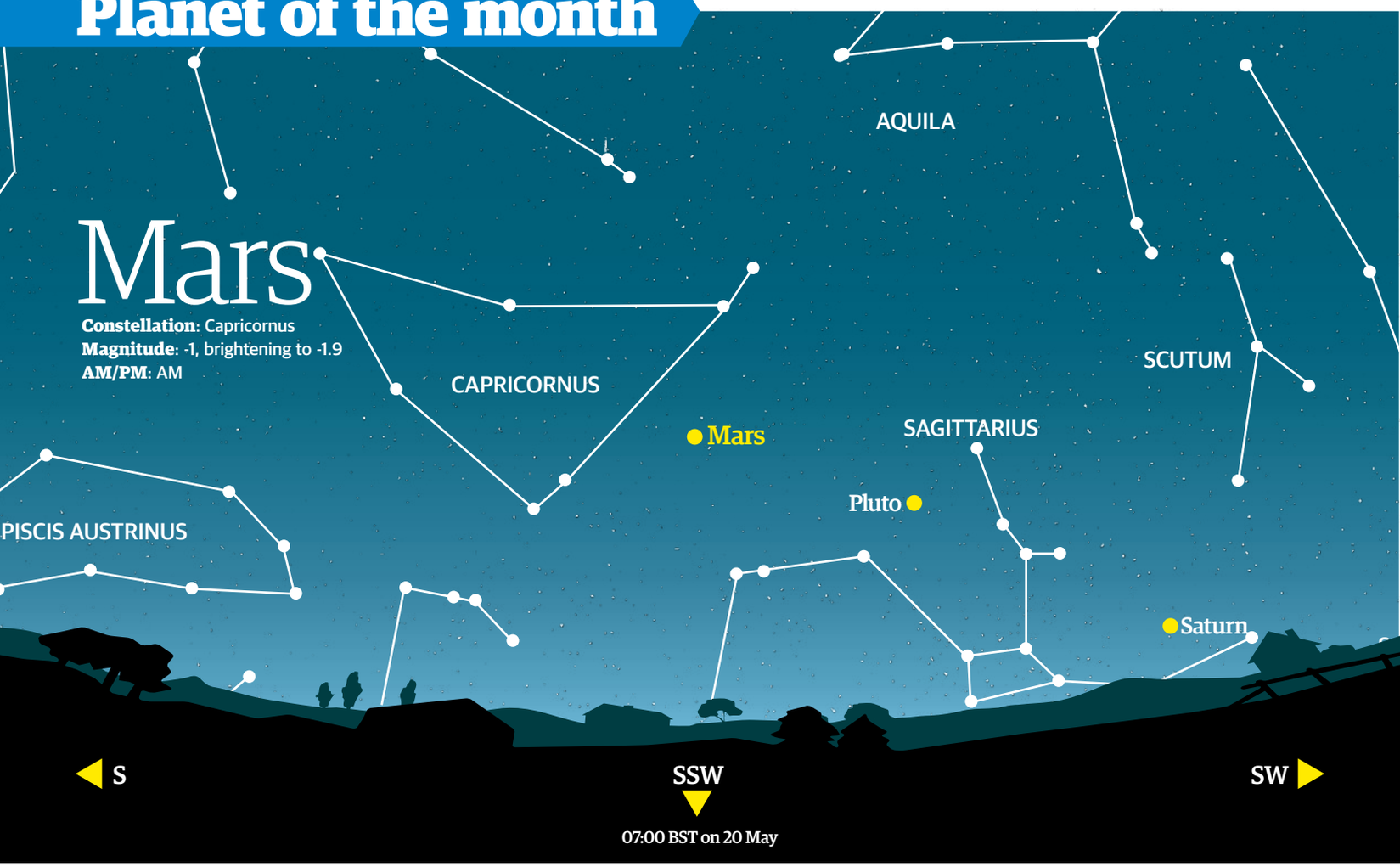
Although most people will have seen Sun dogs, solar haloes and Sun pillars, far fewer will have seen a circumzenithal arc because they appear almost overhead, and most of us are too busy looking at the panoramic view around us – or staring at the screens of our phones – to tilt back our heads and look that far up in the sky very often. It's a shame, because occasionally what looks like an upside down rainbow can be seen high above the Sun, almost overhead. This is a circumzenithal arc, a curve of rainbow-coloured light which, as its name suggests, is the brightest segment of a ring centred on the zenith, the overhead point in the sky.

Sun dogs, also known as parhelia, are easy to spot with just the unaided eye

This month's planets

The Red Planet dazzles in the morning sky, while Jupiter, Venus and Mercury are visible for evening astronomers

Planet of the month



By the time you read this hopefully a new space probe will have blasted off safely from California and be well on its way to Mars. However, unlike previous landers – the Vikings, Phoenix and all the various Mars rovers – NASA's InSight lander will be looking down into the structure of the Red Planet instead of staring out across its ruddy landscapes. InSight will study the internal structure of Mars and monitor it for signs of seismic activity. Instead of sending back thousands of pretty pictures of Mars' wide-open spaces, rust-hued mountains and salmon-pink sky, InSight will be making precise measurements for serious analysis back on Earth. InSight is carrying a very basic camera though, so we will at least get to see her landing site in Elysium Planitia, a quarter of the way between where Curiosity landed and the landing site of Viking 2.

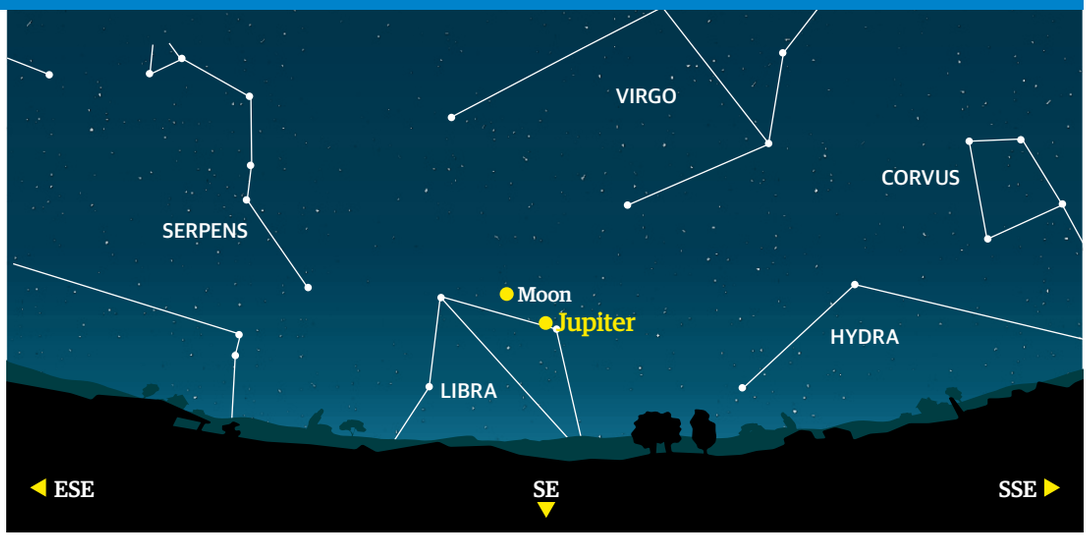
At the end of July Mars will be fascinating to observe – its brightest for many years as it reaches opposition – and as May ends the Red Planet is really gearing up for its grand summer performance. As May draws to a close, Mars will be rising in the east at around 1.30am, already an obvious naked-eye orange-red 'star' in Capricornus, shining at magnitude -1, making it brighter than every star in the sky except Sirius. By 20 June Mars will have brightened considerably to become a striking, magnitude -1.9 orange-red spark rising at midnight.

Sadly, brightness isn't everything; through the whole of our observing period Mars will never climb very high above our horizon. It would be impressive indeed if it were to climb high in the sky to blaze above us, but unfortunately it won't. Instead it will only trace out a shallow arc above the south-eastern horizon before the brightening sky washes it from our view. It is always worth looking at Mars any chance you get, so be sure to set your alarm and go out to see it shining low in the sky to the left of Saturn and Jupiter. Be aware though that if there are any tall buildings, hills or trees on your southern skyline they may well hide Mars from your view, so check that now, in case you need to work out a Plan B. If you need to find a good Mars-viewing location, look for somewhere with a clear horizon in that direction, maybe across a lake, and you'll be guaranteed a fine view right through the summer.

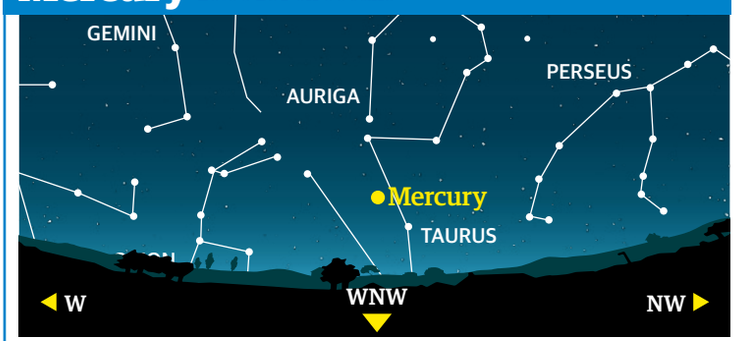
Mars is attractive in its own right of course, but between 2 and 4 June you'll see a waning gibbous Moon drift past it, passing above it – a great photo opportunity to whet the appetite for what is to come in just over a month's time.

Jupiter 20:00 BST on 27 May

Constellation: Libra
Magnitude: -2.5
AM/PM: PM
Throughout our observing period the planet is visible from sunset right through the evening and into the small hours, so it will be possible to watch changes on the planet as the hours pass. You'll also be able to see the four Galilean moons slowly shifting position. The planet is currently in one of the least-obvious zodiacal constellations, Libra, but the planet itself is so bright that you don't need to be able to identify the stars around it to identify it. Shining at magnitude -2.5 it is the brightest object in the evening sky apart from the Moon and Venus, which will be opposite it in the sky. The Moon passes above Jupiter between 27 and 29 May.

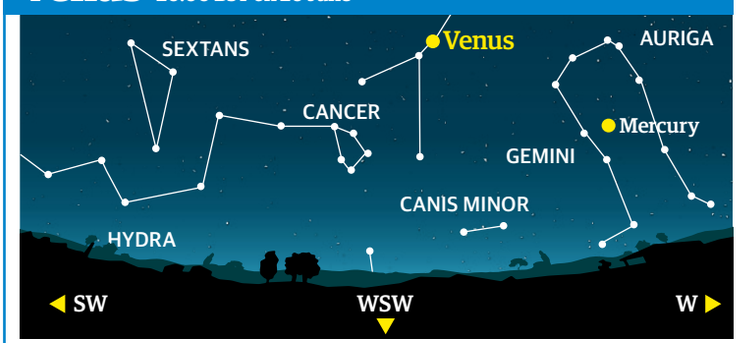


Mercury 20:00 BST on 06 June



Constellation: Taurus
Magnitude: -0.7
AM/PM: PM
At the end of May, Mercury is technically a morning object, but it will be too close to the Sun to be seen. On 6 June the planet will pass by the Sun, and then begin a rapid climb up into the evening sky, pulling a little further away from the Sun each day. By 20 June Mercury will be an evening star to the lower right of much brighter Venus. It will still be quite low in the north west, but it should be easily visible to the naked eye as long as you have no trees or buildings in the way.

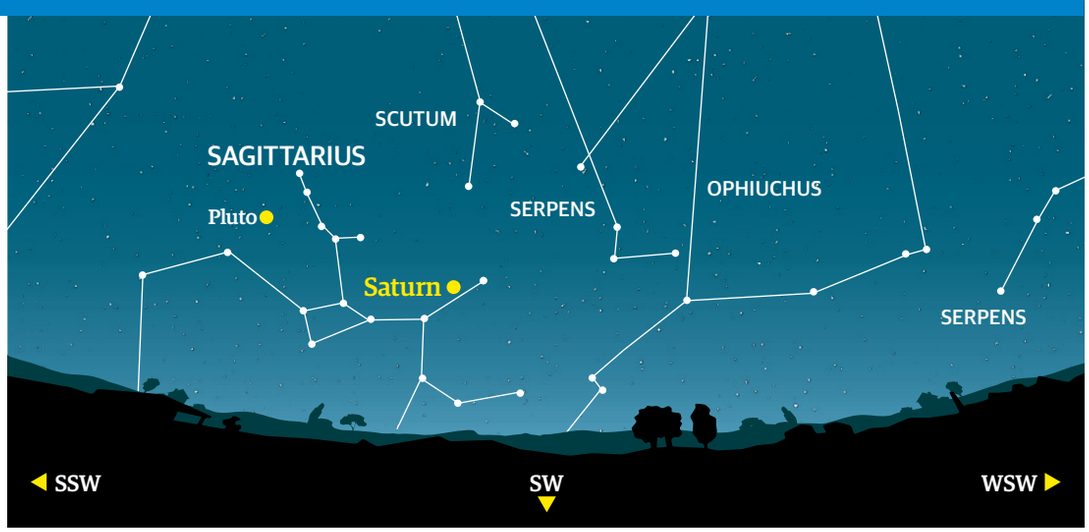
Venus 20:00 BST on 20 June



Constellation: Gemini into Cancer
Magnitude: -4
AM/PM: PM
Venus will first become visible in the twilight as a spark of light high in the north west. As May ends the planet will drift out of Gemini and into Taurus. On the 19 and 20 June Venus will glide through M44, the famous 'Beehive Cluster' in Taurus. A few days earlier on the 16th a beautiful young Moon will shine five degrees away from the Moon, on its left. By then Venus will be setting more than two hours after the Sun and will be a striking sight in the dark sky.

Saturn 04:00 BST on 15 June

This will not be the best of months for Saturn observers, unfortunately. Although the famous 'Ringed Planet' is reasonably bright - magnitude 0.2 means it is almost as bright as Rigel, the blue giant star in Orion - and obvious to the naked eye, its low altitude in the northern sky will reduce its visual impact and appeal. The planet will be shining just above the famous 'Teapot' of Sagittarius all through this month, never climbing very high in the sky, and any obstructions on your southern horizon could well hide it from your view. Look for the Moon almost sitting on top of Saturn on the morning of 1 June, when they will be less than two Moon widths apart.



Top tip!

As with other lunar features, you'll enjoy your best view of Mons Pico when it is close to the terminator.

Moon tour

Mons Pico

Explore one of the most isolated mountains on the lunar surface

The ancient, light-and-dark dappled surface of the Moon is dominated by three types of geological features – craters, seas and mountains. Look at the Moon through a telescope, even a small one, and you'll see mountains everywhere. Some stand alone on the edge or in the middle of one of the maria, the dark seas of frozen lava, while others form long ranges that curve across the seas like the long-buried fossilised spines of dinosaurs being eroded from the rock. Others still form the jagged rims of its craters.

Our tour destination this month is a smaller, much less imposing mountain to the north of the Moon. Mons Pico – or Mount Pico – is a small nub of a mountain, 25-kilometres (15.5-miles) long, 15-kilometres (9.3-miles) wide, and 2.4-kilometres (1.5-miles) in height, which sounds impressive, but Pico isn't as high as even the hundredth-tallest mountain on Earth. In fact, it is only around the same height as Mount St Helens, the American volcano that famously blew its top in May of 1980.

So, clearly it's not Pico's height that makes it worth seeking out. What then? It's the mountain's isolation. Mons Pico can be found in the far north of the huge Mare Imbrium basin, a short distance to the south of the famous dark-floored crater Plato. It stands out – and is so easy to find – because there really isn't much else around it. To the north-west is a small v-shaped range of much smaller peaks, the Tenerife Mountains, and directly north of Pico is a short chain of craters that look like holes left in an antique table by woodworm, but they're so tiny you'll need very high magnification to see them.

Pico might not be as high as other lunar mountains, but just like its taller relations it casts a shadow, and when the terminator – the line between night and day – is nearby that shadow can be very striking, and makes Pico stand out very clearly from the dark, rolling plain of Mare Imbrium. At full Moon, with the baking Sun straight overhead and all surface relief banished by the harsh glare, the mountain is reduced to a bright spot, as white as a dot of correction fluid on paper. Conversely, when sunlight strikes Mons Pico at a shallow angle the mountain casts a shark-tooth of

shadow that makes it stand out starkly, even at low magnification through a small telescope.

Pico might not be well known to casual observers of the Moon, but it is to science-fiction fans and space-exploration enthusiasts. Iconic space artist Chesley Bonestell painted the mountain several times in the giddy pre-Apollo years; it features in the groundbreaking 1951 book *The Conquest of Space* and also in one of his illustrations for the A Trip To The Moon feature in the 1946 issue of *Life* magazine. And fans of Arthur C Clarke's *Odyssey* series will recognise Mons Pico as the site of humanity's repository of biological and computer viruses.

So when can you see Pico this month for yourself?

As luck would have it, Pico is well-placed for observation at the start of our observing period. On 24 May the terminator will have just swept over the mountain and it will be a striking feature, looking like a sharp piece of bone sticking out of the Moon with a dark shadow cast behind it to the west. For the next few days it will be bathed in more and more sunlight. The shadow will gradually shrink back to the foot of the mountain until full Moon on 31 May, when Pico will look like a white dot beneath the dark blue-grey circle of Plato.

By 4 June Pico will begin to become more apparent again as the terminator creeps back over it, this time from the other direction. By now the Moon will be at its waning gibbous phase in the pre-dawn sky, so seeing Mons Pico emerging from the darkness will mean having to get up early, but as you look at it you'll be able to see Mars, now very bright, in the same area of the sky too.

This month's naked eye targets

The summer stars and the Milky Way are now visible in the early hours...

Hercules

Vega (Alpha Lyrae)
Vega is the sixth-brightest star in the sky, and marks another corner of the Summer Triangle. In 12,000BC Vega was the Pole Star, and it will be again around the year 13,727. It is one of the most luminous stars in the Sun's neighbourhood.

Deneb (Alpha Cygni)
Deneb is the brightest star in Cygnus, the Swan, and marks one corner of the Summer Triangle. It is a blue-white supergiant star that lies around 2,600 light years from Earth (its precise distance is still uncertain), but at magnitude 1.25 it is, surprisingly, only the 19th-brightest star in the sky.

Vega

Cygnus Star Cloud
Running down the left-hand side of Cygnus is a large, hazy patch. This is the Cygnus Star Cloud, and when you look at it you're gazing straight down the sweeping curve of our spiral arm towards the Milky Way's centre. Through binoculars it is revealed to be a haze of millions and millions of stars.

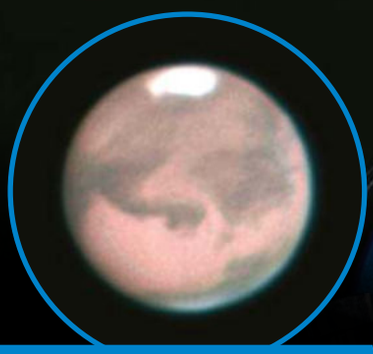
Deneb

Altair (Alpha Aquilae)
Blue-white Altair marks the final corner of the Summer Triangle, and with a magnitude of 0.77 it is the 12th-brightest star in the sky. Only 16 light years away, Altair is one of the closest naked-eye stars to our own Sun. It rotates so rapidly its poles are forced to flatten down.

Delphinus
Delphinus is a very small constellation, but a favourite of many stargazers. It has the shape of a tadpole or a comma, and is supposed to represent a dolphin in the sky. Its brightest star is only magnitude 3.8, but because it is so compact this star pattern is very eye-catching.

Delphinus

Altair



How to...

Observe surface detail on Mars

Known as the Red Planet due to its reddish hue, the fourth rock from the Sun will come to opposition this summer. Here's how to see its surface detail...

You'll need:

- ✔ At least a small telescope
- ✔ Selection of eyepieces (moderate to high power)
- ✔ Coloured filters (blue and orange)

Mars has probably been the one planet throughout history which has drawn us to speculate about its nature, history and its surface time and time again. From the belief that it was or represented the God of war, to first explorations using a telescope, to the infamous 'canals' discovery – later shown to be spurious – which gave credence to the idea that it might be inhabited, this barren world has been the stuff of myth and legend.

Even in the modern world of remote rovers trundling along its surface, there is still the pull for amateur astronomers to view it through their own telescopes, and there is much to see, even through a relatively small telescope.

Due to the relative orbits of Mars and Earth, every couple of years the Red Planet comes into opposition, that is, it's seemingly directly opposite the Sun in our skies, and is also closer to us than at other times. This is a good time to view the planet as it will appear larger, so surface detail will be easier to see. Even though it can be relatively close to us, Mars is smaller than Earth and so will never look particularly large, but there are many features within the grasp of an amateur telescope. The planet has polar caps much like ours, but these are made from frozen carbon dioxide instead of water, and one or both is often visible. There are large features such as the Hellas basin; Olympus Mons, the largest known volcano in the Solar System and a feature known as Syrtis Major, which is triangular in shape and darker than the surrounding surface.

It is even possible to see thin clouds, again made of frozen carbon dioxide ice crystals, and sometimes the surface can be almost completely obscured by a planet-wide dust storm, which can quickly blow up in the thin Martian atmosphere. Although this on the face of it can be disappointing, it is interesting in and of itself, and the dust will settle after a time and restore your view of the surface. You'll probably need a fairly high-power eyepiece to get a good view, and coloured filters can help.

> "There are many features within the grasp of an amateur telescope"

Tips & tricks

Locate the Red Planet

During this observing period, Mars can be found in the constellation of Capricornus (the Horned Goat).

Check visibility

Because it's low down, detail on Mars' surface may be blurred by the Earth's atmosphere. For the very best views, you should wait for a clear night with reasonable observing conditions.

Increase the magnification

Use a moderate- to high-power eyepiece for the best views.

Use averted vision

Fine detail can often be seen using peripheral vision, so don't look directly at the surface, but slightly away.

Select your filters

Depending on what you're interested in observing, an orange-coloured filter can improve the contrast of surface detail.

Choose your moment carefully

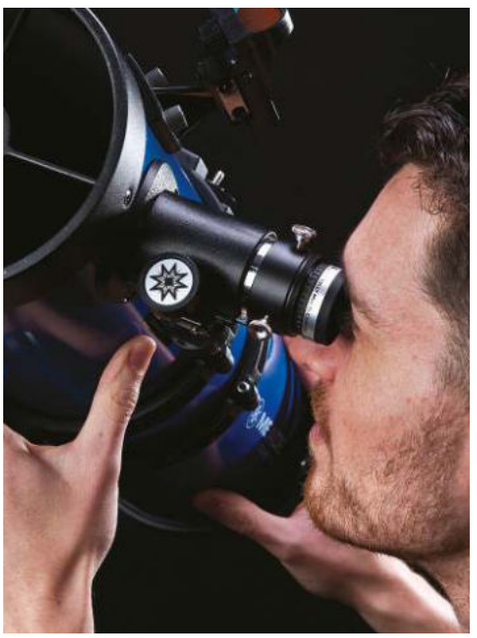
Around opposition is usually the best time to observe a planet...

As the Earth draws nearer to Mars through the months of June and July the apparent size of the disc increases. This will give you the largest viewable disc to see any of the detail and features of Mars. Use as high a magnification as you sensibly can, but drop the power if detail is too blurred or too faint. Using an orange filter will definitely increase the contrast of features on the disc.

Send your photos to
space@spaceanswers.com

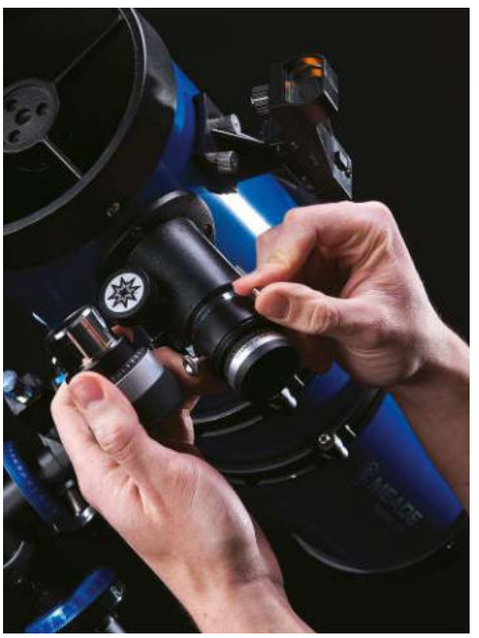
1 Research what you can see

You should do your research in what features will be visible for the night you are observing. You can then focus your attention on specific details and ensure that you're prepared.



2 Locate Mars with your telescope

This should be fairly easy as the Red Planet will now be bright, shining at magnitude -2.8. Use your finderscope to locate the planet and follow up with your main tube.



3 Improve your magnification

Centre the planet carefully in the field of view and steadily increase the magnification by changing your eyepieces. Begin with a low-power eyepiece and work your way up.

4 Take time to adjust

Allow your eyes to get used to the view. The longer you look, the more you are likely to see. If you have come from a lit-up area then you should give your eyes at least 20 minutes to adjust.

5 Use coloured filters

Experiment with coloured filters. Orange is the go-to choice for picking out a selection of features, but blue will bring out the contrast and clarity of the planet's polar ice caps.

6 Enjoy the view!

There are a few weeks either side of opposition to enjoy all that Mars has to offer. You can challenge yourself to see how many features you are able to spot!

Blue Horsehead Nebula (IC 4592)

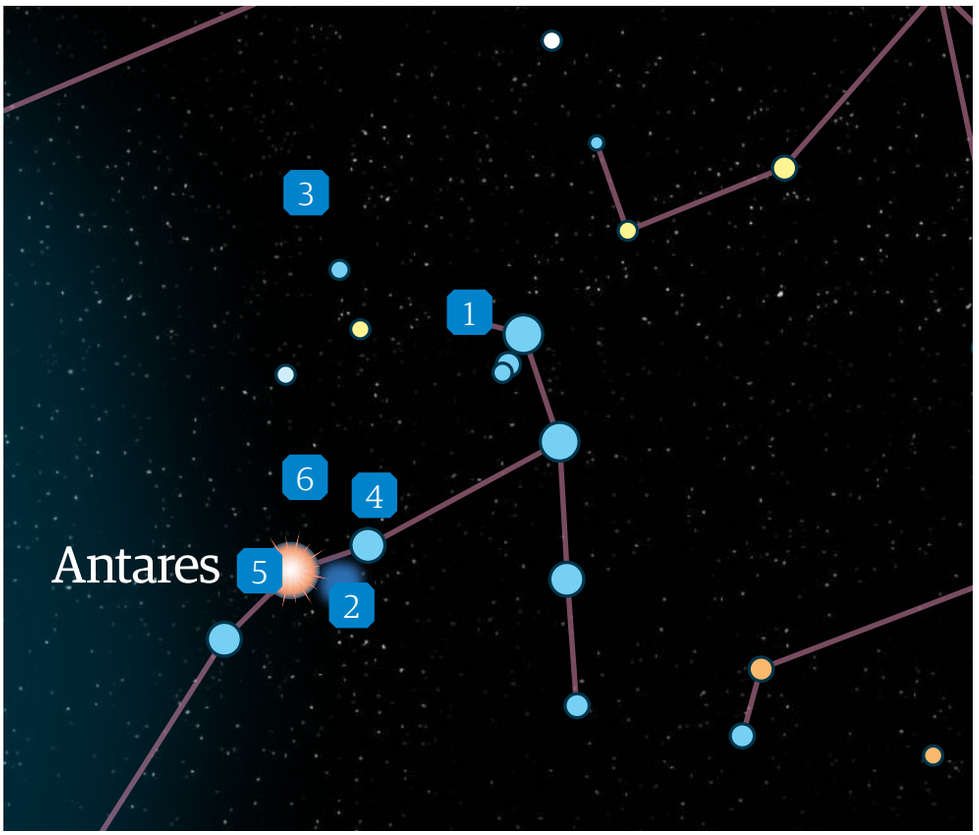
Deep sky challenge

Summer sights

You have to stay up late this month to see many deep-sky objects, but it's definitely worth it

Although the skies never get truly dark at this time of year in the Northern Hemisphere, there is still plenty to see if you are prepared to stay up late. The chances for clear skies are improved, too. There are open star clusters, globular star clusters and nebulae all available for the intrepid explorer armed with a telescope. You will probably notice that the Milky Way, the sweep of one of the spiral arms of our own galaxy, is now more visible, and seems to be arcing more north to south than in the winter and early spring.

Messier 80




Antares (Alpha Scorpii)

1 Blue Horsehead Nebula (IC 4592)

You'll need a large-aperture telescope to see this reflection nebula well, as it has a fairly low surface brightness. Due to this, this nebula – which shouldn't be confused with the Horsehead Nebula – should be imaged in order to be observed in its entire glory. IC 4592 appears blue, with star Nu Scorpii playing the role of the horse's eye.

2 Messier 4

A bright globular star cluster close to the star Antares that's roughly the same apparent size as the full Moon. If you have exceptionally good conditions, you'll be able to see the cluster with the naked eye. Binoculars with magnifications of 10x50 reveal a bright core, surrounded by a halo of light. Small telescopes show Messier 4 as a fuzzy patch of light, while medium and large instruments uncover individual stars and a central bar structure.

3 Messier 107

Sometimes known as the 'Crucifix Cluster' due to its bright core suggesting a cross shape, you'll need a medium magnification in order to see it well. You'll need at least a six-inch telescope to resolve the brightest stars in the cluster's outer region, while 12-inch telescopes will resolve stars across the entirety of Messier 107.

4 Messier 80

This is another bright globular star cluster with a very tight core, which is an interesting comparison to Messier 4. You'll need an eight-inch telescope to reveal the cluster's bright nucleus and extended halo, whilst larger instruments are needed in order to resolve individual stellar members – in particular, 12-inch telescopes will uncover the brightest members.

5 Antares (Alpha Scorpii)

Antares, which means the 'rival of Mars', is a red supergiant star. Just like its 'twin', the star gives off a very ruddy colouration. Not technically a deep-sky challenge object, since it is readily observable with the naked eye, the challenge comes from splitting it and resolving its companion – a greenish secondary.

6 Rho Ophiuchus cloud complex

This is a real challenge due to its low altitude and brightness. You'll require a UHC filter, which can help on a large aperture telescope at low power and – due to its faint appearance – is best imaged to play up stunning contrast and clarity.

"The challenge comes from splitting Antares and resolving its companion – a greenish star"

How to...

Capture the close approach between Venus and M44

On 20 June, the planet will come close to the beautiful open star cluster known as the Beehive Cluster. Here's how to image it with ease...

You'll need:

- ✔ DSLR camera
- ✔ Equatorial tracking mount
- ✔ Wide-field telescope or telephoto lens

Occasionally we can see objects seeming to come close to each other in the night sky. This is, of course, just a line-of-sight effect, as the objects themselves can be vast distances apart. In this case we have a planet in our Solar System sidling up to a huge cluster of stars over 500 light years away, or at least it looks like that from our point of view.

Venus is a planet quite similar in size to the Earth, although shrouded in dense sulphurous clouds. This makes the planet very reflective. You really can't miss Venus, as it is one of the brightest objects in the night sky. As it has an orbit about the Sun inside that of the Earth we find that it exhibits phases, just like the Moon.

The phase changes slowly as it orbits about the Sun from our point of view, and so is always interesting to look at, even though its thick clouds make it otherwise featureless. On 20 June it will be showing a gibbous phase, nearly 74 per cent illuminated, which will make it very bright indeed at around magnitude -4. This will be in stark contrast to the much fainter open cluster of M44. This can make photographing the two objects together quite a challenge. The skill is in getting the stars of the cluster to show up without over exposing the planet. There are of course ways around this problem, but first you have to capture a few good images of both objects in order to make them look good in a final picture. Much can be done during the processing of your image, which is explained on the next page.

There is another challenge, too, which is that both objects will be in the twilight and not against a truly dark sky. This will make the star cluster seem all the more faint. It is best to leave your imaging to later in the evening, when the sky will be darker. However, both objects will be much closer to the horizon. To get both objects in the same field of view you will need a short focal length telescope with you camera attached, or a telephoto or zoom lens giving up to 400mm focal length. Experimentation is the key here.

"The skill is getting the stars of the cluster to show up without over exposing the planet"

Tips & tricks

Finding M44
The star cluster M44 can be quite tricky to find in a twilight sky, but this evening it rests just south of Venus.

Framing your shot
You'll need to experiment; you'll need a set-up which will give you around a 4° field of view to get the cluster and Venus in comfortably.

Exposures
It is best to experiment, but you'll need a fairly short exposure for Venus and a much longer one for the cluster.

Tracking mount
Getting a good image will be down to the number of exposures you take and a mount which can keep up with the rotation of the Earth.

ISO settings
It's a good idea to experiment with the ISO setting on your camera. Try using around ISO 800 to capture the cluster.

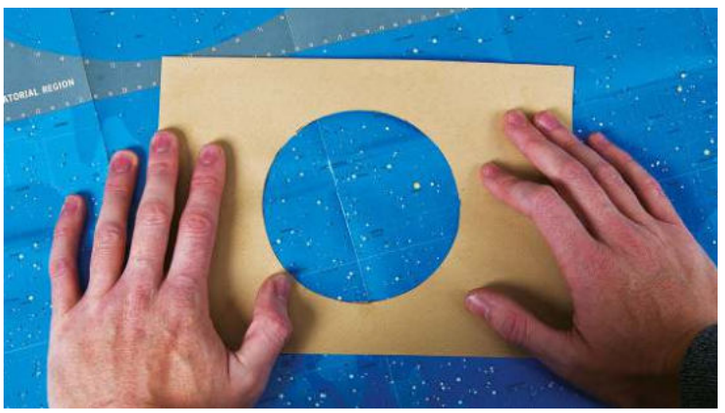
Create a composite

Due to the large difference in the brightness you will need to take two different exposures

Use a fairly short exposure to capture Venus. Take several with differing exposure lengths to get the best image of the phase of the planet. Without moving the camera, take many longer exposures to capture the star cluster. Venus will be over-exposed, but this is okay because you can combine the two good images in an image-processing package such as Photoshop for a perfect image of both objects.

Send your photos to
space@spaceanswers.com

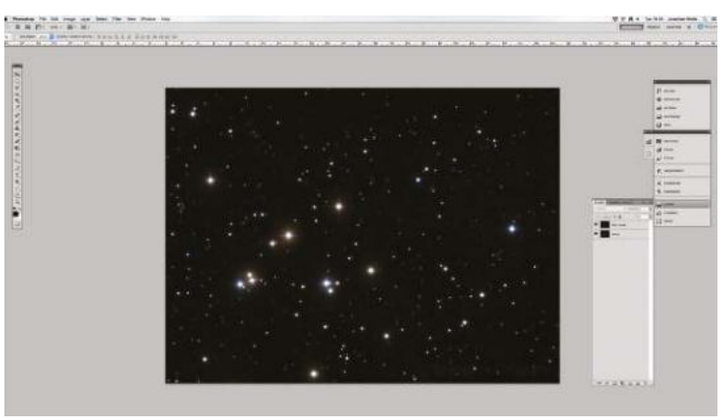
1 Polar align your telescope
Set up and polar align your equatorial tracking mount and make sure the camera/telescope combination is fixed firmly.



2 Frame your shot
Locate Venus and the star cluster and frame your shot through the viewfinder or view screen.

3 Experiment with exposures
Take several shots of Venus at different exposure lengths and then do the same for M44, altering the ISO value to 800.

4 Choose your image
Pick the best image of both Venus and the star cluster and import them into an image-processing package such as Photoshop.



5 Make the most of layers
Copy and paste the image of the star cluster over the image of the well-exposed Venus.

6 Putting it together
Draw a circle around the over-exposed Venus and delete it to show the properly exposed image underneath.

The Northern Hemisphere

Summer has arrived – but while the nights are lighter, there are plenty of targets to get stuck into this month

The constellations of Boötes (the Herdsman), Libra (the Scales) and Ursa Minor (the Little Bear) hang proud on the lighter canvas of a summer sky this month. It'll take the Sun until gone 21:00 (BST) to dip well below the horizon, so you'll need to wait a little longer to catch fainter targets.

A selection of star systems can be split with the right equipment in Boötes, while several stars in the constellation – including orange giant star Arcturus (Alpha Boötes) dazzles at a magnitude of -0.05. Meanwhile, if you're looking for a challenge, dim deep-sky objects including barred spiral galaxy NGC 5792, globular cluster NGC 5897 and lenticular galaxy NGC 5890 are worthy targets.

Using the sky chart

This chart is for use at 10pm (BST) mid-month and is set for 52° latitude.

01 Hold the chart above your head with the bottom of the page in front of you.

02 Face south and notice that north on the chart is behind you.

03 The constellations on the chart should now match what you see in the sky.

Magnitudes

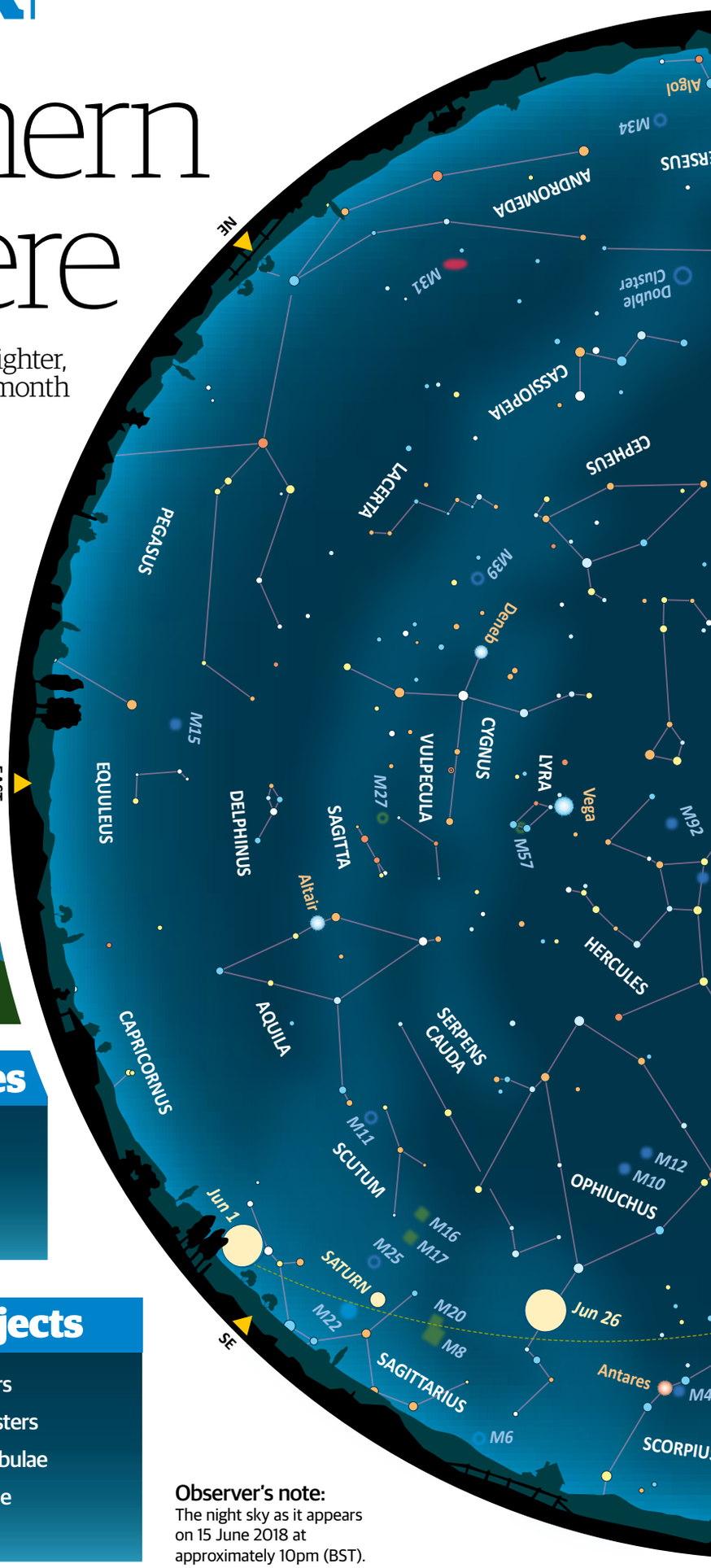
- Sirius (-1.4)
- -0.5 to 0.0
- 0.0 to 0.5
- 0.5 to 1.0
- 1.0 to 1.5
- 1.5 to 2.0
- 2.0 to 2.5
- 2.5 to 3.0
- 3.0 to 3.5
- 3.5 to 4.0
- 4.0 to 4.5
- Fainter
- Variable star

Spectral types

- O-B
- A
- F
- G
- K
- M

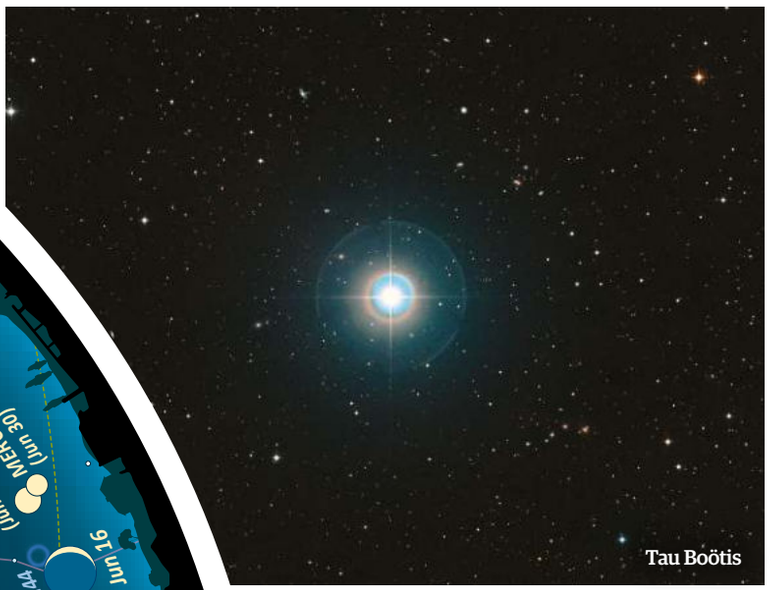
Deep-sky objects

- Open star clusters
- Globular star clusters
- Bright diffuse nebulae
- Planetary nebulae
- Galaxies



Observer's note:
The night sky as it appears on 15 June 2018 at approximately 10pm (BST).

The Northern Hemisphere


Tau Boötis


Ursa Minor and Ursa Major


NGC 5897

Astroshots *of the month*

Send your astrophotography images to **space@spaceanswers.com** for a chance to see them featured in **All About Space**

Peter Louer

Teide National Park, Tenerife

"I retired to the beautiful island of Tenerife in 2013. One of the top sites in the world for astronomy, the Caldera in Teide National Park is at an altitude of over 2,000 metres. With a dry atmosphere and limited light pollution, it has proved to be the ideal location to combine my hobbies of photography and astronomy. Here are a few shots of the Horsehead Nebula (Barnard 33), the Pleiades (Messier 45), the Moon and the Milky Way; all a true pleasure to image at such a fine location."

The Pleiades (Messier 45)

Moon setting over North Tenerife

Horsehead Nebula (Barnard 33)

The Milky Way over Teide National Park, Tenerife

Jellyfish Nebula & Sharpless 248

Graham Hard

London, UK
Telescope: Sky-Watcher 250PDS

"I took up astrophotography in April 2012 and soon realised that galaxies and deep-sky objects were very limited with regard to viewable detail, so I started looking at how to photograph these targets. Now I often collect image data of 12 or more hours to produce my images. I love to shoot all aspects of the night sky. Comets, planets, the Sun, Moon and a wide selection of deep-sky objects. I live in an area with a poor night sky, so I am experimenting with narrow-band imaging which can improve the negative effects of light pollution."

Ian Griffin

Las Cruces, New Mexico
Telescope: Takahashi FS-60C

"I have a long love of astronomy, and have observed the night sky for many years with binoculars and a telescope. I did my first 'real' astrophotography in 1996, when I used a 35mm SLR (film) camera to take photos of Comet Hyakutake. I took a tripod out into the desert here in Las Cruces and just experimented with exposures. Later, I bought a ten-inch Dobsonian for viewing, and within a week was taking pictures through the eyepiece. Within a few more weeks, I knew I wanted to get serious with astroimaging."

Send your photos to... @spaceanswers space@spaceanswers.com

Celestron 114 LCM Computerised Telescope

Locate majestic sights with just the press of a handset button

Telescope advice

Cost: £349.00 (approx $479.40)
From: David Hinds Ltd
Type: Newtonian Reflector
Aperture: 4.49"
Focal length: 39"

Best for...

- Beginners
- Medium budget
- Planetary viewing
- Lunar viewing
- Bright deep-sky objects

If you're a beginner that wants to get to know the night sky but don't fancy finding the stars yourself, this telescope could be what you're after. The Celestron Lightweight Computerised Mount (LCM) 114 telescope has the built-in technology to do all the automatic slewing across its alt-azimuth axes, while remaining lightweight enough for you to carry around with minimal discomfort.

When you unwrap the package, you are greeted with a fine bundle capable of pointing you to a variety of locations on the celestial map. The three major kingpins of the bundle include the tripod, the computerised altazimuth mount and the Newtonian Reflector telescope tube with its StarPointer red-dot finderscope attached. The additional accessories include two eyepieces of nine- and 25-millimetre focal lengths, providing a magnification of 111x and 40x respectively, an accessory tray, The SkyX astronomy software and an LCM Hand Control that has 4,033 celestial objects completely at your disposal. All these accessories provide a solid platform from which you can observe the night sky. However, there is one thing missing, and that is something to power the mount. Not included in the pack, but very much needed is either eight AA batteries or a 12V battery pack. If batteries are your intended power source for this mount, we would highly recommend to always have another eight AA batteries spare.

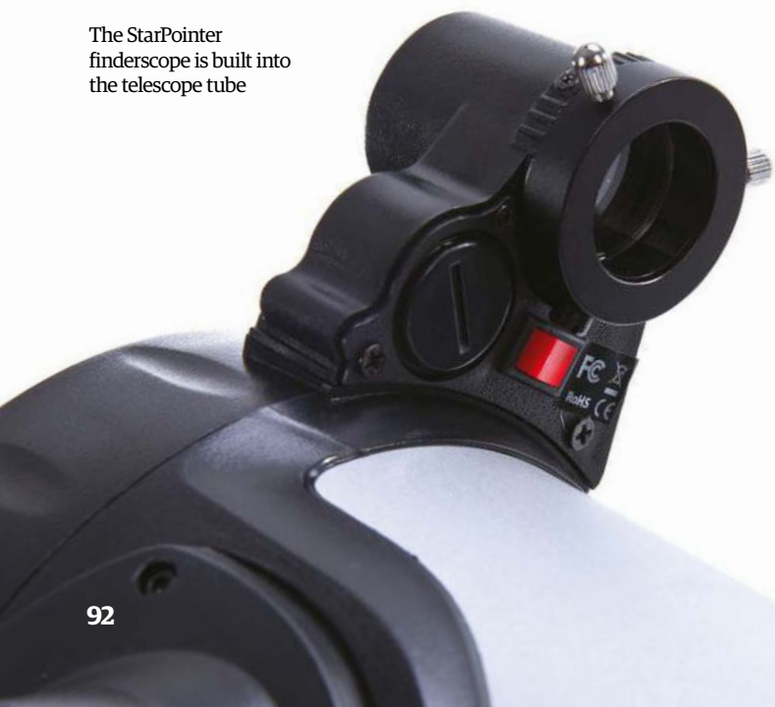
Either eight AA batteries or a 12V battery pack (not included) is needed to power the telescope

As for the assembly, it was all too easy. There was no issue in this respect, and even if there was, the Quick Set-up Guide clearly explains all the steps in order to piece this puzzle together and is available online at **celestron.uk.com**. The next item on the 'preparing the telescope' agenda is the alignment of the telescope. Much like riding a bike, there is a learning curve that could be hard for the extreme beginner at first. However, once you have the swing of things it will only take a matter of minutes to calibrate and align the telescope. Depending on your knowledge and experience there are five possible ways to calibrate the telescope, and that is by completing one of these processes: SkyAlign, Auto Two-Star Align, Two-Star Align, One-Star Align or Solar System Align.

Based on our experience, it is best to use the SkyAlign option. This option will ask you to enter your current time, date and location, and then all that is needed is a three-star alignment process. Given the vast knowledge of constellations and stars in this issue, as well as the SkyX software that comes with the bundle, identifying three stars shouldn't prove a hard task, and will be a massive time-saver when it comes to preparing your telescope for the night-time viewing.

Now on to the huge magnifying glass – the Newtonian Reflector and its optics. It provides a focal ratio of f/9, which returns crisp views of many bright objects, but lacks plentiful light gathering capabilities, making it less than ideal for astrophotography. However, as this telescope caters towards a beginner, that is of not much importance. Along with its fully coated optics and over 4,000 objects in the computer's database, there are plenty of stars, planets, galaxies, nebulae and clusters to gaze upon, and appreciate the finer details.

The optics for this telescope are best suited for bright astronomical objects such as the Moon, Jupiter and its moons, Saturn and its rings and so on, but it can also



The StarPointer finderscope is built into the telescope tube

"The computerised mount makes for an easy experience"

There are over 4,000 celestial objects in the handset database

The bundle comes with a 25mm and 9mm eyepiece

tackle some of the brighter Messier objects too, such as The Orion Nebula (M42). Although this object is now gone from sight until wintertime, there are still plenty of bright Messier objects available, which will be explained in more detail in our observing session.

There is one aspect of the bundle that we think can be improved, and that is the tripod. Although it is lightweight and easy to carry, it sacrifices the stability and sturdiness of the telescope. When the telescope was fully set up it felt like a knock or a nudge could easily make it wobble, and that can disrupt your sights, which can be especially annoying if there is a breeze.

We took the Celestron 114 LCM telescope out on a spring night, which is not ideal, but the conditions were well enough for us to look at a handful of targets before the session ended. After the set-up and alignment were all done, which only took about ten minutes, we decided to first view Jupiter, as it was at its highest point in the sky. The wonderful Jovian bands were clearly visible, and the specks of light orbiting the gas giant, also referred to as the Galilean moons, were resolved and visible. Moving beyond Jupiter, we turned our attention to the Great Cluster in Hercules (M13) with its magnitude of 5.8. This made for a great sight, as the telescope could resolve the bright concentration of stars at the centre of the globular cluster, and showed a crisp gradual decline in brightness towards the edges.

To increase the difficulty we tested out the Leo Triplet, which is a collection of three galaxies in the constellation of Leo, with the brightest galaxy having a magnitude of around nine. Using the 25mm eyepiece, which offered the best light-gathering capabilities, the triplet was still quite faint. Although there were smudges of light, the telescope wasn't quite able to observe the galaxies in any great detail. The fact that we located and gazed upon three galaxies by just pressing the buttons on a hand control was extremely impressive.

By taking everything into account, including the build, design, optics and ease-of-use, we would highly recommend this telescope to a beginner that wishes to view a variety of celestial gems, but wants a machine to do the finding! The computerised mount makes for an easy experience; once you have mastered the art of alignment and calibration you have the night sky at your fingertips. The price of the bundle is a fair reflection on its quality and capabilities, which doesn't break the bank as well.

WORTH £259

WIN!

AN ALTAIR GPCAM2 290M MONO CAMERA

Up the astronomy ante with this monochromatic CMOS

Courtesy of Altair Astro, we have one Altair GPCAM2 290M monochrome camera to give away to one lucky reader. Ideal for the astronomer who wants to go beyond simply observing through an eyepiece, this CMOS will take you to the next level in creating stunning shots of a selection of targets.

The GPCAM2 290M is incredibly easy to attach to your telescope, as well as your computer, and packs a huge punch with its highly impressive Sony Exmor IMX290 CMOS sensor. With a high sensitivity reading while maintaining a low read for background noise, you can unlock a plethora of deep-sky objects. Additionally, it's more than able to take clear and detailed images of the Moon and the Sun - provided a solar filter is attached to the telescope - as well as video astronomy.

The advantage of a monochrome camera over a colour camera is that you can be much more selective with your intended wavelength. Although additional filters would be required, it allows for less background noise and a clearer view of some magnificent targets - from the planets of our Solar System and galaxies to nebulae and star clusters.

ALTAIR

Congratulations to Mark Henly, who is the winner of the Vixen 'grab-and-go' bundle

To be in with a chance of winning, all you have to do is answer this question:

On 20 June 2018, which asteroid is at opposition and in prime position for observations?

A: 4 Vesta B: 2 Pallas C: 7 Iris

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Book The Little Book of Black Holes

Cost: £14.95 (approx. $20.60) **From:** Princeton University Press

Talking and explaining about the elusive nature of black holes is a difficult task alone. That's why we applaud the job that Steven Gubser and Frans Pretorius have done in putting together the exquisite *Little Book of Black Holes*.

As far as books about these objects go, it is not overwhelming with complex information and theories that will boggle the mind, averting interest. As it's about an object that hasn't been directly observed, there is a great deal of science behind them in order to explain its existence. For this reason a decent scientific background would have been a welcome addition to *The Little Book of Black Holes*.

The book starts with the introduction of the LIGO results of the merging black holes and what it means for the scientific community. Starting the book this way gives a solid foundation to base the rest of the information, which was huge news when it broke. From there, the true science of the situation is unveiled over the course of 200 pages and by the end of the book, we found we had an excellent understanding of the modern physics that sculpt our universe and the role that black holes play.

Accessories Vixen Porta II Alt-azimuth Mount (including tripod)

Cost: £299.00 (approx. $410.00) **From:** Opticron

Of all of the many alt-azimuth mounts we have reviewed at **All About Space**, this mount is up there with the best. We immediately saw why a lot of people spend good money for this mount, as it is sturdy, reliable and easy to control and transport.

Being an alt-azimuth mount, it is clear that it was built with the amateur astronomer in mind. The mount and tripod together weigh 5.7 kilograms (12.5 pounds), making it a portable piece of kit. It employs extendable aluminium legs capable of reaching 1.3-metres (4.2-feet) tall and has a robust build, providing a stable foundation so that minimal jogging of the telescope will occur. The Vixen Porta employs a dovetail joining plate, making it versatile in switching telescope tubes and - combining all of these aspects with the fact it has slow-motion handles, intended for finely tracking celestial objects - makes for everything an amateur astronomer needs.

Although it is not capable of providing the more advanced astronomical techniques such as motor-driven star tracking – which is better suited for astrophotography – this mount is ideal for eyepiece astronomy and navigating through the night sky with ease.

"This mount is sturdy, reliable and easy to control and transport"

App Scope Nights

Cost: £4.99 / $4.99 **From:** Egg Moon Studio

One of the things that stands between an astronomer and the night sky is the weather, and in order to get the best out of a night, preparation is key. Disregarding all of the planetarium apps with augmented reality and such bells and whistles, *Scope Nights* targets an aspect of astronomy that provides observers with all the information they need.

With up-to-date forecasts across the globe you can get the best out of any night. It has a distinct 'poor, fair and good' observing summary of the current and future weather, styled with the popular English 'red, amber and green' colour code to symbolise when it's ideal to grab your telescope and go. This app also provides a much more complete analysis of the weather and has a detailed light pollution map, which is extremely helpful in deciding which location is best to pitch up your telescope.

Overall we were extremely impressed with the app, especially given the price of it. It has an excellent design interface, which makes all aspects very accessible and visually enjoyable.

Accessories Vixen NPL 4mm & 25mm Plössl eyepieces

Cost: 4mm: £45.00 (approx. $62.00) / 25mm: £49.00 (approx. $67.50) **From:** Opticron

With two representatives of Vixen's New Plössl (NPL) range, we were very excited to test out the variety and contrast between the two. We also wanted to analyse the NPL series as a collective and see how they hold up against other eyepieces.

On the whole, these eyepieces are very impressive, as they provide clear and concise images. We tested both of these out on the Moon for a simple challenge. Unfortunately the 4mm went over our telescope's maximum magnification and returned sub-standard views. When we tested the 25mm it returned a superb view of the Moon, showing incredible clarity and contrast which held up towards the edges of the field of view.

The NPL series are of very good quality, structure- and optics-wise. They are comfortable on the eye, which is often underestimated in importance, especially as you're spending a night looking through it. With the 20, 25, 30 and 40mm eyepieces, they also offer a twist-up eyecup. Based on our experience, we recommend you make sure that the eyepieces suit the telescope magnifications – especially with the smaller sizes – to ensure you return the finest views.

Roberta Bondar

Her time in space put her in the history books as the first female Canadian and neurologist in space

Bondar was the second Canadian in space, behind Marc Garneau

© NASA

On 22 January 1992, Roberta Bondar proudly represented a country of over 35 million people as she became the first Canadian woman to cross the threshold of Earth into space. Her story is an inspiration, and it all stems from childhood wonder and fascination.

Born in the city of Sault Ste. Marie in Ontario, Canada on 4 December 1945, Bondar dreamt of reaching space ever since she was a little girl putting together plastic model rockets. She's previously said her faith in technology combined with her naivety, whether it was naivety about the physical training or the poor space exploration opportunities in Canada at the time, led her to become the astronaut that flew on the Space Shuttle Discovery.

Before she did that she gained a very diverse education and training portfolio. Bondar holds a bachelor's degree in zoology and agriculture, a master's degree in experimental pathology and two doctorates in neuroscience and medicine, giving her a wide spectrum of knowledge, which is favourable for being chosen as an astronaut. In 1983, the Canadian space program selected Bondar as an ideal candidate for further training, which began the following year.

The travesty that was the Challenger disaster occurred just two years after her training began, which completely shook the world and made people seriously reconsider the career path of being a astronaut. Although it is incredibly rewarding and life changing, the Challenger disaster showed it comes at a very high risk. This didn't sway Bondar, however, as in 1992 she was assigned the role of 'Payload Specialist' on STS-42.

Launched from the Kennedy Space Centre in Florida, United States on board the Space Shuttle Discovery, Bondar and six other flight crew members flew to a low-Earth orbit. Eight days were spent orbiting the Earth, consisting of 129 orbits around our home planet and travelling over 4.7 million kilometres (2.9 million miles). In this time, Bondar conducted important experiments in the unique microgravity environment in the Spacelab as the first neurologist in space.

> "Bondar conducted important experiments in the unique environment in the Spacelab"

Bondar claims that her time in space completely changed her perspective in the sense that she could see the whole planet beneath her and realised that humanity should work together, and described the experience as a "reality check". Bondar retired from the Canadian Space Agency on 4 September 1992, after her one and only spaceflight. Her work afterwards includes working as part of a NASA research team for over a decade and pursuing a professional photography career. She also opened the Roberta Bondar Foundation, which is a not-for-profit charity centred on environmental awareness.

Bondar's influence on Canada and the whole world has been heavily recognised. The most noticeable mentions among her many accolades include the Officer of the Order of Canada, the Order of Ontario, the NASA Space Medal and more than 22 honorary degrees, as well as her induction into the Canadian Medical Hall of Fame.

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WINNER
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SRP £559

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PARABOLIC NEWTONIAN REFLECTOR

Standard Specification
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- Highest Practical Power (Potential) x300
- Diameter of Primary Mirror 150mm
- Telescope Focal Length 1200mm (f/8)
- Eyepieces Supplied 10mm & 25mm
- x2 Deluxe Barlow Lens
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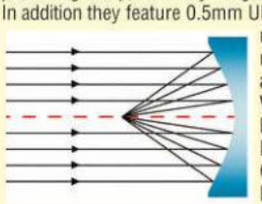

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